CHAPTER VI

ST. MARYS RIVER

A. STATUS OF THE ECOSYSTEM

1. Ecological Profile

Watershed Characteristics

The St. Marys River connects Lake Superior and Lake Huron. The river originates in Whitefish Bay on Lake Superior between Point Iroquois, Michigan and Gros Cap, Ontario and flows 112 km to Lake Huron. The lower St. Marys River has irregular shorelines and contains four large islands: Sugar, Neebish and Drummond on the American Side and St. Joseph on the Canadian side, as well as approximately 100 small islands less than 4 km^2 in area. Sugar Island separates the main river into the Lake George and Lake Nicolet channels (Figure II-2).

The surface geology of the southwestern St. Marys River valley is composed primarily of lacustrine sediments and moraines. On the southwestern edge of the valley, in Michigan, level lake bed plains are interrupted by gently rolling plateaus, low rounded ridges, sand dunes, bluffs, and marshlands. In Ontario, on the northeastern edge of the valley, knobby Precambrian rock is partially covered by a thin layer of till or lacustrine clay. Much of the bedrock of the basin consists of volcanic and granitic rocks of Precambrian origin in the north, and Ordovician and Silurian dolomites in the south.

The primary influence on surficial geology of the St. Marys River basin during recent times has been the fluctuating water levels. As recently as 3,000 years ago, crustal rebound lifted up rock ledges at Sault Ste. Marie to a level higher than the water level of Lake Huron. This changed the strait connecting Lakes Superior and Huron into the St. Marys River. The influence of fluctuating water levels on the St. Marys valley during the last 4,000 years has been to erode surface deposits, leaving remnant beaches, sand dunes, and other littoral features. Lacustrine clays form most of the soil of the area south of the Canadian Shield.

There are a number of watersheds that drain into the St. Marys River. By far the most important is the Lake Superior basin, which also includes the Goulais River on the Canadian side. Other drainage basins that discharge to the St. Marys River are much smaller. On the U.S. side, these include the Charlotte, Little Munuscong, Munuscong and the Gogomain Rivers. These drain about 64% of the immediate watershed. On the Canadian side are the Big Carp, Bar, Little Carp, Root, Garden, Little Garden and Echo Rivers.

Hydrology

Hydrologically, the St. Marys River may be divided into three major reaches: the upper river, extending from Whitefish Bay to the St. Marys rapids; the rapids; and the lower river, extending from the foot of the rapids to the De Tour Passage at Lake Huron. The upper river rapidly decreases in width in its 22.5 km of length and is characterized by sandy shores, with emergent wetlands occurring only in protected areas. The rapids separate the upper and lower river, and in an area 1.2 km long and 1.6 km wide, the river drops 6.1 m. The lower river is divided into two main outlets, Lake Nicolet and Lake George, and is slower moving.

Water currents of the river are highly variable and influenced by the quantity of discharge to the river from Lake Superior and the water level of Lake Huron. Current velocities are impeded by high surface water levels in the river's mouth at Lake Huron, by easterly or southerly winds, or by low barometric pressure. High surface water levels in Lake Superior result in greater discharge to the river and increased current velocities. Discharge to the river has been partially controlled by compensating gates at the Sault Locks since 1921.

Recorded outflow from the St. Marys River fluctuates greatly. The mean flow rate for the 124 years of record (1860 - 1984) is 2,200 m^3/sec, and have ranged from a minimum of 1,200 m^3/sec to a maximum of 3,700 m^3/sec. Since the completion of the Long Lake and Ogoki Diversions in the 1940s, in which some waters originally draining north into James Bay were diverted to Lake Superior, there has been an increase in the mean discharge by about 8%.

During the period April to October 1983, 74% of the total discharge measured at Sault Ste. Marie flowed through the Lake Nicolet reach. The balance flowed through Lake George.

Water levels of the St. Marys River are subject to three types of fluctuation: seasonal; long range, and short term. Seasonal fluctuations are over a period of one year. These are the most regular, with highest water levels occurring during the summer and lowest during the winter. There is about a 0.3 m change in water level during the year.

Flushing rates were calculated and found to average 1.31 lake (Nicolet) volumes per day. Because of this, and the hydrographic features of the lower river, materials in suspension or solution tend to be transported through the length of the St. Marys River in a short period of time.

Habitats and Biologic Communities

A series of narrow channels and broad lakes exist throughout the St. Marys River. The shorelines are without major areas of settlement except for the cities of Sault Ste. Marie, Michigan and Ontario. Rocky shores characterize the narrow reaches and clay, sand or mixed detritus-sediment combinations are found in shallow areas. The shorelines tend to be inhabited by emergent vegetation, sometimes uninterrupted for 3 to 5 km or more. The 12 km tract of hardstem bulrush and bur reed that extends northward from the Charlotte River is an example.

Annual production of biomass in these wetlands is dominated by three emergent plants: hard stem bulrush, giant bur reed and spike rush. Submerged species occur as a diffuse understory of low biomass. Growth that produces the emergent wetlands is vegetative and colonial, usually in monotypic stands. Areal surveys of the last three decades show that these stands tend to be long-lived, and relatively permanent features of the St. Marys shoreline. Rootstocks of the dominant species are present in the hydrosoil year round. They reach maximum biomass late in the growing season and degenerate in winter. Live rootstocks die back rapidly in the spring, yielding their food and nutrient reserves to new shoot growth. A tight cycling of nutrients results from this cycle, leaving little available for invading species.

Lake Superior and the St. Marys River are subject to important wind-driven forces, such as waves and seiches. Strong prevailing northwesterly winds cause formation of large waves which travel long distances before reaching Whitefish Bay and the headwaters of the river. Regions of wide expanse on the lower river have shorelines variously exposed to waves and currents. Shores with the most exposure have no emergent vegetation; the bottom is rock and shifting sand. Where emergent vegetation does occur, least protected sites have square bulrush or spike rush as the dominant vegetation. Most protected sites have hardstem bulrush and bur reed. The west shore of the St. Marys River lies in the lee of prevailing winds and emergent wetlands are more entrenched on this shore.

Upstream of the St. Marys fork at Mission Point and throughout Lake Nicolet and its downstream reaches, submerged wetlands spread as a meadow of low growing plants over bottom sediments wherever the river is broad, the substratum suitable and water clarity good. Twenty-two known species of plants occur in these wetlands.

Diatoms dominate the transient phytoplankton community and the species are characteristic of oligotrophic waters. Seventy-two species have been identified in the Lake Nicolet reach of the river. A mix of planktonic and benthic species has been found in the plume of the St. Marys River in Lake Huron. Benthic populations comprise as much as 40% of the total algal assemblage in terms of cell volume, while the remainder is planktonic. Chlorophyll _a_ concentrations show that planktonic algal biomass varies only slightly from one end of the river to the other.

The species composition of benthic fauna changes from the upper river downstream with downstream communities exhibiting increased oligochaete abundance. Generally, the bottom fauna of the river is indicative of good water quality. However, pollution tolerant species are present near Sault Ste. Marie, Ontario as a result of contaminant loadings to the river. Ephemeroptera, Amphipoda and Mollusca are common and abundant and contribute substantially to the standing stock biomass. Mayflies may be the most abundant species of benthic invertebrates in the river. However, nymphs of two species, _Hexagenia limbata_ and _Ephemera simulans_, are particularly abundant in areas of soft substrate. _Hexagenia limbata_ is most abundant in portions of lakes George and Nicolet and in the lower river where fine sediments occur; _Ephemera simulans_ is more common in the coarser sediments of Lake Nicolet and the upper river. The bottom of the shipping channel, because of dredging, is poor habitat for benthic macroinvertebrates.

Primary fish habitats in the St. Marys River have been classified as (i) open-water and embayments, (ii) emergent wetlands, (iii) sand and/or gravel beaches, and (iv) the rapids (1). Although most species are associated with only one habitat, some are found in more than one habitat and some use different habitats on a daily or seasonal basis. Rainbow smelt, spottail shiners, trout, common white suckers, rock bass, and yellow perch were collected in all habitats (2,3,4).

In general, the open water fish community is dominated by demersal species although two pelagic species, lake herring and rainbow trout, are abundant. Other fish found in open water areas are yellow perch, white sucker, lake whitefish, northern pike, and walleye. Smallmouth bass, chinook and pink salmon, and lake sturgeon are seasonally abundant in open water areas.

Liston _et al_. (4) collected 49 species of fish in the wetlands of the river which serve as spawning, nursery and feeding areas for many species, particularly yellow perch, northern pike, smallmouth bass, bowfin, longnose gar, brown bullhead, and walleye. A similar species mix was found in the sand and gravel beach zones together with some of the small bottom species found in the open water areas. Trout, perch, shiners, and juvenile walleye are common in these areas.

The fish community inhabiting the St. Marys rapids is discrete from the fish communities of other parts of the river. Thirty-eight species have been collected from the rapids (5), many of which are of interest to anglers, including lake whitefish, rainbow trout, lake trout, brown trout, brook trout, and chinook salmon. Important forage species in the rapids are longnose dace and slimy sculpin. Sea lamprey adults are present in the rapids during the spawning season (especially July) and appear to be increasing in number.

Local Ecological Relationships

i) Food Web and Trophic Structure

Emergent plants are by far the most productive component of the river system, some 200 times more productive than phytoplankton, and 40-50 times more productive than submerged plants. Periphyton on submerged shoots of emergent wetland plants have annual productivity of the same order as the phytoplankton. Thus, in the St. Marys system, food production for consumers is concentrated along the edges of the river in emergent wetlands and along the bottom in submerged plant communities.

Among secondary producers, zooplankton represent an important link between phytoplankton and higher trophic levels. Phytoplankton in pelagic zones of lakes and rivers have a low standing stock biomass, but constitute the basis of pelagic food webs. Zooplankton concentrate the energy available from phytoplankton biomass and are then available to fish and other planktivorous feeders.

The zooplankton community emptying into the river from Whitefish Bay consists of some 30 crustacean species. The winter zooplankton community consisted mostly of adult stages of Diaptomus cicilis, Diaptomus ashlandi, Limnocalinus micrurus, and immature copepodids of Cyclops bicuspidatus tomasi. During summer, immature calanoids, adult Cyclops bicuspidatus tomasi and Cladocera dominate the open water environment.

The zooplankton of the lower river is very similar in species composition to the summer community of the upper river, but far less abundant. The zooplankton density in emergent wetlands is more than an order of magnitude greater than the maximum densities found in open water.

The benthic macroinvertebrate community of emergent wetlands in the St. Marys River is taxonomically diverse with a total of 171 recorded species or taxa of aquatic insects. Chironomidae are the richest fauna, with 39 species, with Hemiptera, Odonata and Coleoptera also well represented. However, chironomids and oligochaetes numerically dominate the benthic macroinvertebrate community. Larva of the beetle Donacia sp. are phytophagus and develop within the stems of the macrophyte Sparganium eurycarpum. Larva of the moth Bellura sp. do the same in Scirpus spp. stems. Mayflies, Hemiptera and Odonata are found in more dense macrophyte stands.

Ichthyoplankton studies in the St. Marys River have identified 39 species. Fish larva collected in the river include larva from the river, the tributaries and Whitefish Bay. Rainbow smelt dominate all reaches of the river, spawning in small tributaries or along rocky shorelines. A marked succession of fish larvae is apparent and is the result of differential timing of reproduction by various species in response to environmental stimuli.

ii) Plant Nutrients and Dissolved Gasses

Data on alkalinity, pH, and dissolved oxygen are available for the St. Marys River from a number of sources. Alkalinity is typically 40 mg $CaCO_3$/L (or 0.8 milliequivalents/L), pH ranges between 7 and 8, and dissolved oxygen concentration varies seasonally. Dissolved oxygen concentrations throughout the river are adequate to support all forms of aquatic life and are well above the 5.0 mg/L U.S.EPA recommended limit.

Total nitrogen (TN) ranges from 0.262 to 0.668 mg/L and averaged 0.413 mg/L during 1982-83. Total phosphorus (TP) averages 13 ug/L. The ratio of TN to TP in the photic zone is a useful index for separating lakes into N-limited and P-limited categories. If the TN/TP ratio is greater than 10, algal production is likely to be phosphorus-limited. The average TN:TP ratio for the St. Marys River is 32 but varies during the growing season and always exceeds 10.

iii) Biological Links of the Great Lakes

Many of the fish species in the river undertake seasonal movements from one area to another. For some of these species these movements are only dispersal into adjoining habitats. However, for other species, such as chinook salmon, lake herring and walleye, these seasonal movements may be characterized as seasonal migration.

The parasitic sea lamprey is present within the St. Marys rapids. Twenty percent of the adults captured from Lake Huron tributaries in 1983 were taken at the powerhouse near the St. Marys rapids. Sea lamprey spawn in the St. Marys rapids, in tributaries to the river, and probably at lesser rapids located below Lake Nicolet and Lake George.

There are 172 known species of birds which frequent the St. Marys River and adjacent riparian areas (1). Waterfowl, colonial waterbirds and some raptors have traditionally been useful as indicators of water quality in the Great Lakes. Of these bird groups, species which breed, stage or overwinter on the river are particularly useful. A list of these species is included in Table VI-1. Duffy et al.(1), provide a detailed list of all the St. Marys River bird species.

Waterfowl nest along the shorelines and on islands within the St. Marys River. Census data from the 1980s are not available for most species that breed along the river. However, Weise (6) estimated a density of 8.9 pairs/km^2 of ducks at Munuscong Lake marshes during breeding season. Common goldeneye, mallard, blue-winged teal and black ducks nest in munuscong lake marshes while common mergansers, american coots, Canada geese and occasional northern pintails and common loons nest in emergent wetlands adjacent to the river.

Recent data from aerial surveys (6) show the highest absolute abundance of waterfowl in the river occurs during the fall migration period when virtually all the waterfowl species listed in Table VI-1 occur in the St. Marys River. During the October and November staging and migration period, the dominant species are redhead, scaup, ringnecked duck and mallard (6). The most common species which winter along the St. Marys River are common goldeneye, common merganser and mallard (7), and greater and lesser scaup.

The many islands of the St. Marys River provide nesting sites to colonial waterbirds (8,9). Herring and ring-billed gulls, common terns and great blue heron are present during the spring/summer breeding season. Nesting sites are found throughout the St. Marys River area, but only the herring gull winters here.

Bald eagles are year-round residents of the St. Marys River area. There are two active nests used by bald eagles, one on Sugar Island and one on the Munuscong Lake shoreline. In the winter, eagles are found in the area surrounding the north end of Sugar Island. Approximately 15 pairs of osprey breed on the river. This small but significant number of birds has stabilized since growing rapidly from 1 breeding pair in 1973.

The mammalian fauna of the St. Marys River area reflects the region's transitional position at the northern edge of the Great Lakes hardwood and the southern edge of boreal forests. Some 55 species of mammals inhabit the area, 46 small mammals and 9 large ones.

TABLE VI-1

Waterfowl, colonial waterbirds and raptors which are or could be used as important water quality indicators in the St. Marys River.

Scientific Name	Common Name
GAVIFORMES	WATERFOWL
Gaviidae	Common Loon
Gavia immer	
ANSERIFORMES	
Anatidae	
Branta canadensis	Canada goose
Anas discors	Blue-winged teal
Anas rubripes	American black duck
Anas platyrhynchos	Mallard
Anas acuta	Northern pintail
Anas strepera	Gad Wall
Aythya valisineria	Canvasback
Aythya americana	Redhead
Aythya collaris	Ring-necked duck
Aythya marila	Greater scaup
Aythya affinis	Lesser scaup
Bucephala clangula	Common goldeneye
Mareca americana	American Wigeon
Lophoelytes cucullatus	Hooded merganser
Mergus merganser	Common merganser
Mergus serrator	Red-breasted merqanser
PELECANIFORMES	COLONIAL WATERBIRDS
Phalacrocoracidae	
Phalacrocorax auritus	Double-crested cormorant
CICONIFORMES	
Ardeidae	
Ardea herodias	Great blue heron
CHARADRIIFORMES	
Laridae	
Larus delawarensis	Ring-billed gull
Larus argentatus	Herring gull
Sterna hirundo	Common tern
Chlidonias niger	Black tern
FALCONIFORMES	RAPTORS
Accipitridae	
Pandion haliaetus	Osprey
Haliaeetus leucocephalus	Bald eagle
Buteo lineatus	Red-shouldered hawk
Circus cyaneus	Northern harrier
STRIFIFORMES	
Strigidae	
Bubo virginianus	Great horned owl

Associated with the river are beaver, muskrat, racoon, river otter, American water shrews and the northern water shrew. Muskrat are the most common and the two species of shrews are abundant. Nonriverine species of shrews, moles, mice, squirrels, chipmunks and hares abound. Badger and gray fox occasionally inhabit the area.

Mixed boreal forest and northern Great Lakes forest species of large mammals include numerous white tail deer, moose, black bear, bobcat, lynx, coyotes, red fox and gray wolves within the St. Marys Valley.

Climate

Area winters are cold and snowy, with total snowfall accumulation ranging from a minimum of 0.82 m to a maximum of 4.54 m. On average, permanent snow cover begins on November 21, and remains until April 7th. The 30 year (1950-1980) averages for precipitation (water equivalent) at Sault Ste. Marie, Michigan show an annual mean average of 0.85 m. Monthly variations are significant, with February being the driest month, having a monthly mean of 4.3 mm, while September is the wettest with a monthly mean of 9.9 mm.

The coldest month of the year in the region is January, which averages -10.4°C, while July is the warmest, averaging 17.5°C. Air temperatures are moderated throughout the year by the waters of Lake Superior which seldom freeze. Based on the thirty year period (1951-1980) the average first day of frost is September 27th and the average last occurrence is May 26th. Most summers pass without temperatures reaching 32.2°C and the highest temperature of record is 36.7°C, which occurred in 1888.

The water temperatures of the St. Marys River are near 0°C for four months of the year; annual temperatures of the headwaters in Whitefish Bay range from 0°C to 16°C. Ice forms on the St. Marys River with broad, shallow areas freezing first followed by the deeper, faster reaches.

2. Environmental Conditions

Water Quality

Water quality degradation has resulted from steel and paper mills and municipal sewage treatment plant discharges. Considerable progress has, however, been made since 1970 by Algoma Steel Corporation Ltd. in reducing ammonia-nitrogen, free cyanide, and phenol discharges; by St. Marys Paper in reducing suspended solids loading; and by the municipal sewage treatment plants in improving the removal of phosphorus and organic matter.

A system of transects across the St. Marys River between Whitefish Bay and the outlets of Lake George and Lake Nicolet has been used by the Ontario Ministry of the Environment to monitor water quality (Figure VI-1). Each transect was sampled at several locations from the Canadian shore to the U.S. shore. Transects are numbered by their distance in statute miles upstream (prefix - SMU) and downstream (prefix-SMD) of the Algoma Steel Terminal Basins' submerged diffuser outfall. About 20 samples for each water quality parameter were collected across each transect. The water quality parameters which were measured in most of the studies were phenols, cyanide, ammonia, phosphorus, heavy metals (such as total iron and zinc), and several polynuclear aromatic hydrocarbons (PAHs). In assessing the significance of contaminant concentrations in the St. Marys River, comparison can be made with the Ontario Ministry of Environment (OMOE) Provincial Water Quality Objectives (PWQO), the Great Lakes Water Quality Agreement (GLWQA) specific objectives and the Michigan Ambient Water Quality Standards (Table III-2, Chapter III).

i) Cross Channel Variations in Water Quality

In general, contaminants such as phenols, ammonia, cyanide, iron and zinc, attributable to Algoma Steel discharges, were found along the Ontario shoreline of the river with no transboundary pollution in the main channel upstream of transect SMD 2.6. Typical distribution of contaminants across the main portion of the river is shown in Figure VI-2. The cross channel variation at sampling transect SMD 2.6 indicates that the phenol, ammonia, zinc and iron concentrations increased from the stations located near the Michigan shoreline to those stations adjacent to the Ontario shoreline. Data from 1986-87 indicate that transboundary movement of iron, zinc, and ammonia did not result in exceedences of water quality standards in Michigan waters. However, the mean phenols concentration exceeded the GLWQA specific objective of 1 ug/L in Michigan waters.

Contaminants are confined to the Ontario shoreline as far as Sugar Island. The curving flow at the beginning of the Lake George channel creates a zone of high velocity towards the Sugar Island shoreline (10) because of the division of flow between the Lake Nicolet Channel, west of the island and the Lake St. George, northeast of the island. Secondary currents enhance the transverse mixing process across the Lake George Channel (11). Thus, contaminants attributable to upstream industrial discharges which were confined to the Ontario shoreline of the main portion of the river will be found along the Sugar Island shoreline of the Lake George Channel. Additional inputs of contaminants from the Sault Ste. Marie, Ontario East End Water Pollution Control Plant (WWTP) to those of upstream industrial discharges result in the persistence of contaminants in the downstream reaches.

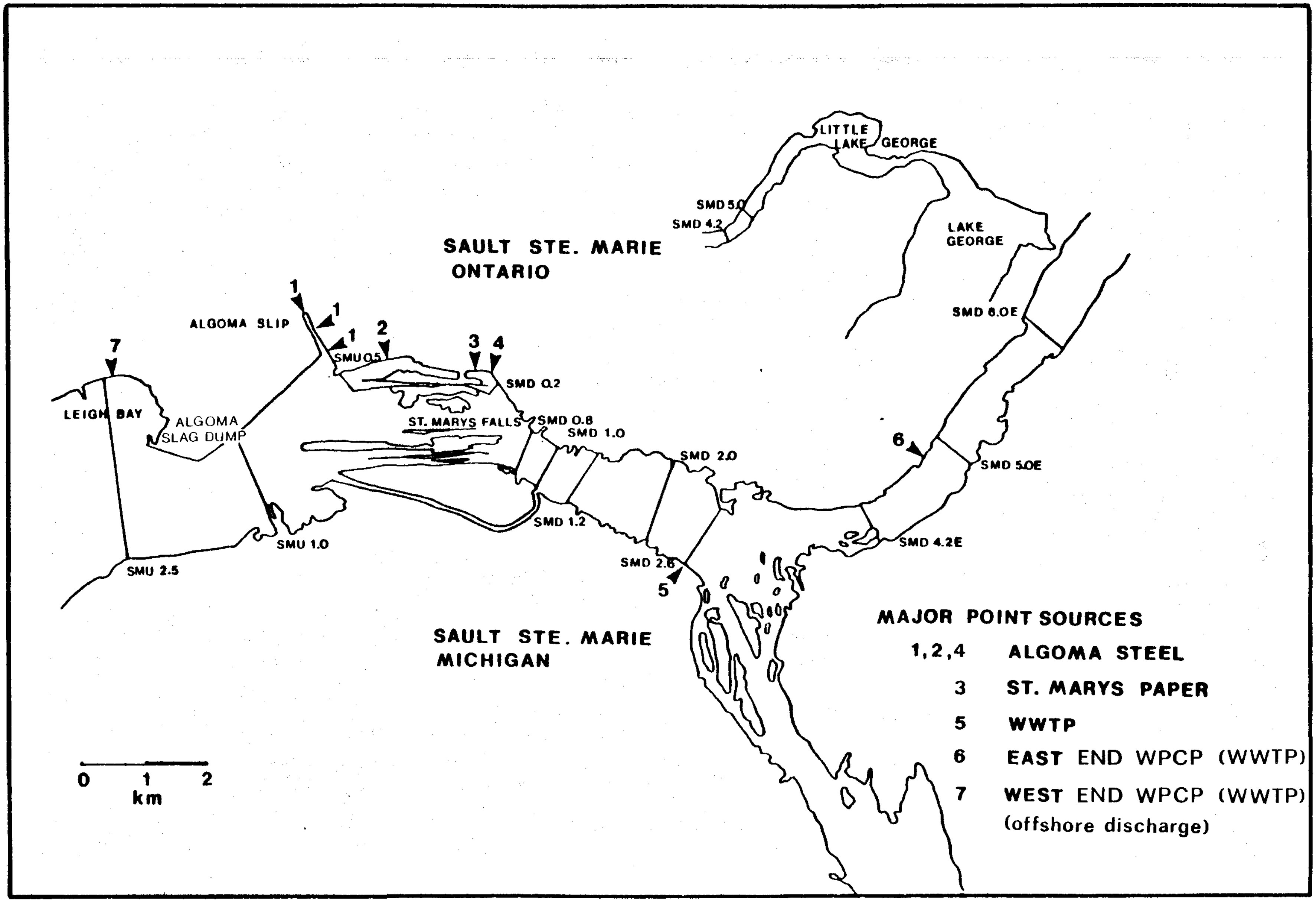

FIGURE VI-1. Sampling transects and major point source dischargers.

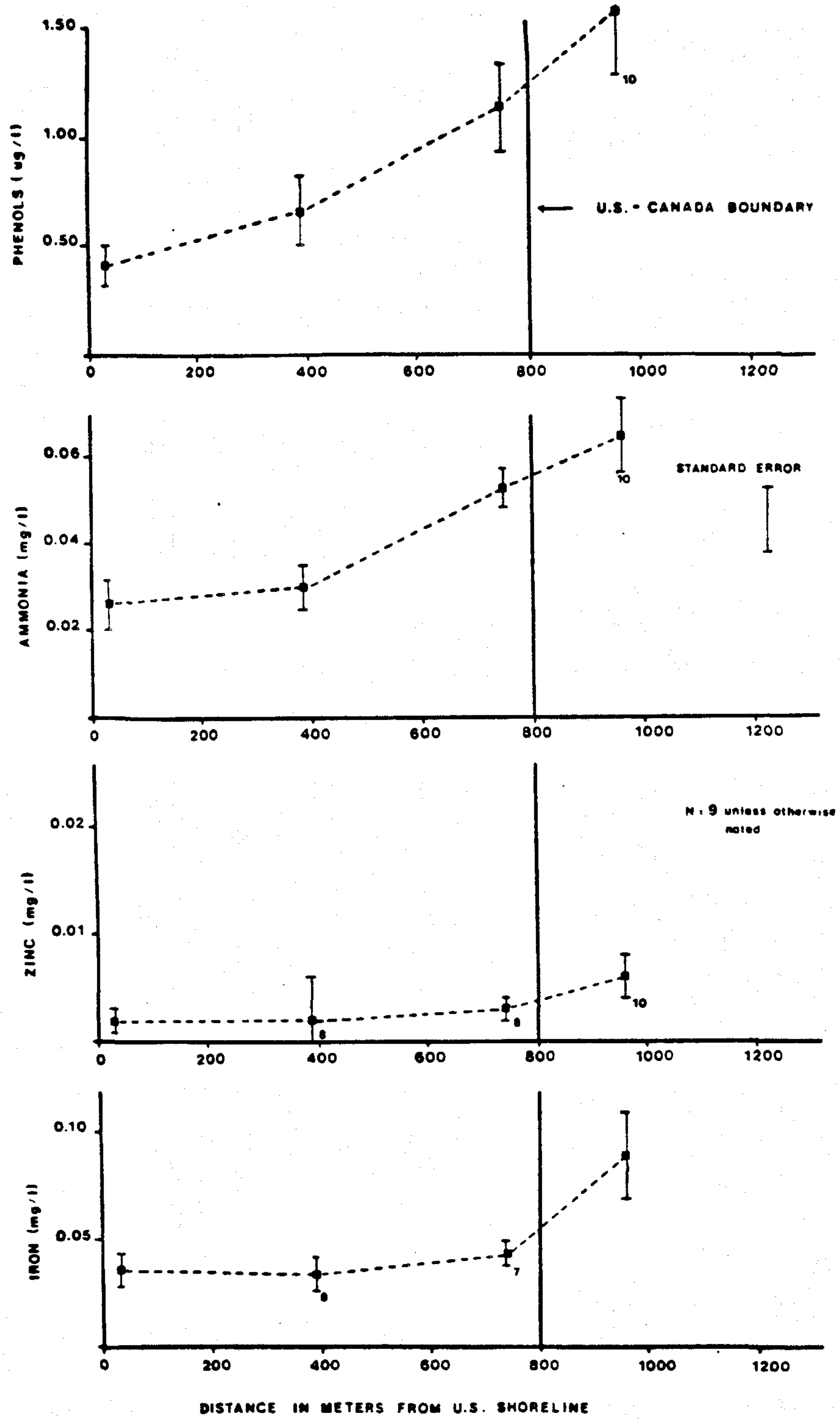

FIGURE VI-2. Distribution of contaminants across St. Marys River at transect SMD 2.6 (1986-87).

Hamdy and LaHaye (12) documented the transboundary pollution of ammonia in the Lake George Channel downstream from the East End WWTP. Ammonia concentrations increased by 20% in Michigan waters near Sugar Island.

ii) Longitudinal Variations in Water Quality

Bacteria:

In 1986, analyses for fecal coliform (FC), fecal streptococci (FS), E. Coli and P. aeruginosa in the St. Marys River indicated several problem areas. Geometric mean densities of FC along the Canadian shoreline were greater than the PWQO (100 organisms/ 100ml) at stations near storm sewers and major industrial outfalls. For example, at two stations (SMD 0.8 and 1.0) immediately below these outfalls and in the vicinity of some of the storm sewers, the mean FC densities over 3 days were 477 and 428/100ml. The corresponding densities for E. coli were 311 and 271/100ml; for FS, 24 and 13/100ml; and for PA, 4/100ml. At a further 1.5 km downstream, densities of FC were below the PWQO.

Bacterial densities were also elevated below the outfall of the Sault Ste. Marie, Ontario East End WWTP in the Lake George Channel. The mean densities over 3 days at two stations (SMD 5.0E and 7.9E) downstream of this facility were: FC, 184 and 182/100ml; E. coli, 120 and 153/100ml; FS, 24 and 19/100ml; and PA, 5 and 7/100ml.

Densities of fecal coliform and streptococci along the U.S. shore were below the respective PWQO at all stations, with the exception of immediately downstream of the Edison Sault Electric Company Canal (SMD 1.2). Compliance with Michigan's fecal coliform standard (200 cells/100ml) is determined on the basis of the geometric mean of any 5 consecutive samples taken over not more than a 30 day period. Because only 3 samples were collected from this site, comparison with Michigan water quality standards is not possible. However, the 3-day geometric means of E. coli, fecal coliform, fecal streptococci and P. aeruginosa were 1,149 organisms, 2,250 organisms, 233 organisms, and 20 organisms, respectively, per 100ml. The sources may be combined sewer overflows that discharge to the Edison Power Canal (see urban runoff section).

Phenols:

The redevelopment of the Great Lakes Power Limited hydroelectric generating station in 1982 resulted in changes in the distribution of river flow at the regulating works (Figure VI-3). The portion of total river flow along the Ontario shoreline increased from 21% to over 40% of the total river flow. This increase in flow is in part responsible for the reduction of river concentrations of phenols, cyanide and ammonia (12).

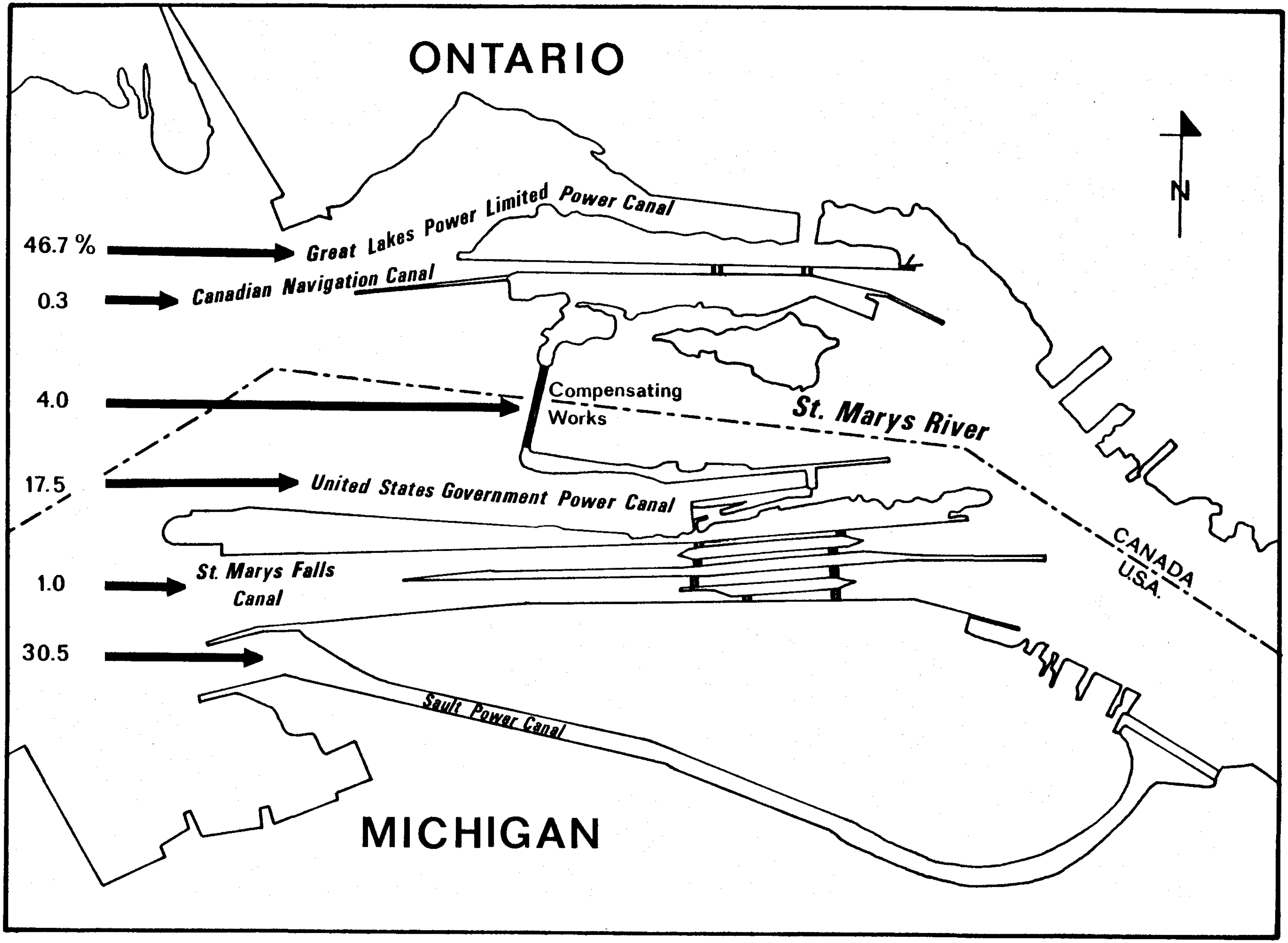

FIGURE VI-3. Average flow distribution (%) at the St. Marys River Rapids (2.2×10^3 m^3/s post 1982).

The year-to-year variations of total phenol concentrations measured at various distances downstream from the Algoma Steel discharges are shown in Figure VI-4. There is a downward trend of phenol levels over the years. Mean phenol levels 300 m downstream of the Algoma Terminal Basins outfall (at river range SMD 0.2) declined from 50 ug/L in 1973 to 15 ug/L in 1980 and to 1.2 ug/L in 1986.

In 1986, all stations downstream of Algoma Steel discharges had phenol levels approaching the PWQO and Great lakes Water Quality Agreement specific objective of 1 ug/L. However, phenols exceeded the objective in the Algoma Steel Corp. Slip (3.6 ug/L) and at the mouth of the Slip (3.4 ug/L) in 1986. The Algoma Slip is a ship loading and off-loading facility located upstream of the Terminal Basins and power canal.

In 1986-87, average phenols along the Michigan shoreline were below the PWQO and the GLWQA specific objective of 1 ug/L.

Ammonia:

The ammonia concentration distribution along the Canadian shoreline downstream of the Algoma Steel discharge, is illustrated in Figure VI-5. The 1986 levels along the Canadian shore exhibited significant decreases as compared to previous years. The calculated unionized ammonia concentrations were below the PWQO and GLWQA specific objectives of 0.02 mg/L.

The ammonia concentration increased downstream of the Sault Ste. Marie East End WWTP (see Figure VI-4, SMD 5.0). The impact of the WWTP effluent is localized, as concentrations at the Lake George Channel outlet were the same as those observed at the beginning of the Lake George Channel (0.046 mg/L) upstream of this facility.

Cyanide:

The distribution of free cyanide along the Canadian shore in 1974 and 1980 indicated peak concentrations 300 m downstream from the Algoma Steel discharge and uniformly low concentrations further downstream (Figure VI-6). The 1986 levels indicate a decline from the previous years, and uniformly low concentrations from upstream to downstream. All levels were in compliance with the PWQO of 0.005 mg/L and the U.S.EPA chronic AWQC of 0.0052 mg/L.

Heavy Metals:

During 1986-87 the concentrations of total iron in the St. Marys River ranged between 0.018 and 0.69 mg/L and no distinct longitudinal variations were noted. Just downstream of the Terminal Basin's outfall (SMD 0.2), the average concentration was 0.06 mg/L with a maximum of 0.69 mg/L. This maximum was one

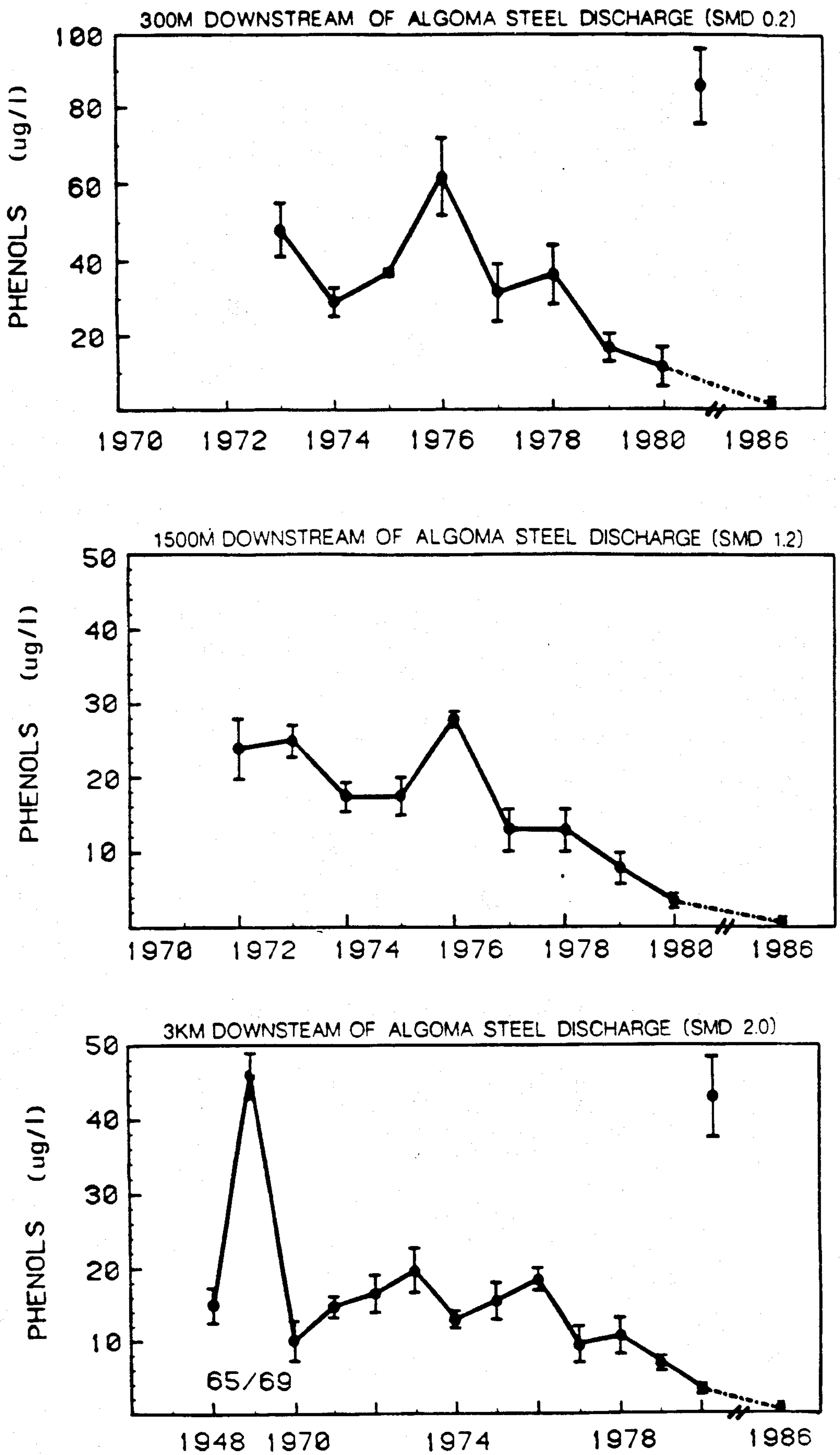

FIGURE VI-4. Phenol concentrations in the St. Marys River at various distances downstream of the Algoma Steel discharge along the Canadian shoreline.

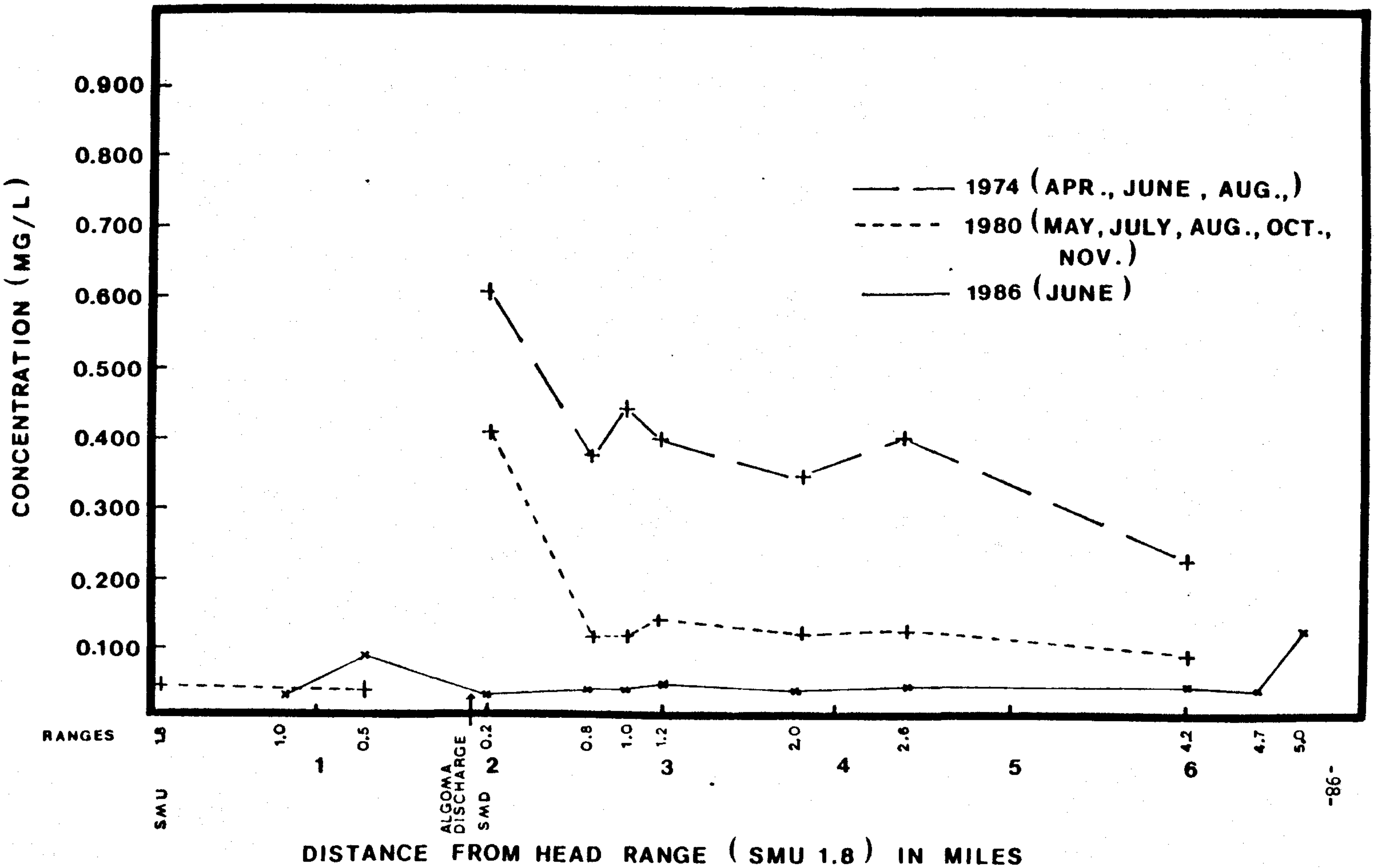

FIGURE VI-5. Ammonia distribution and yearly trends along the Canadian shore.

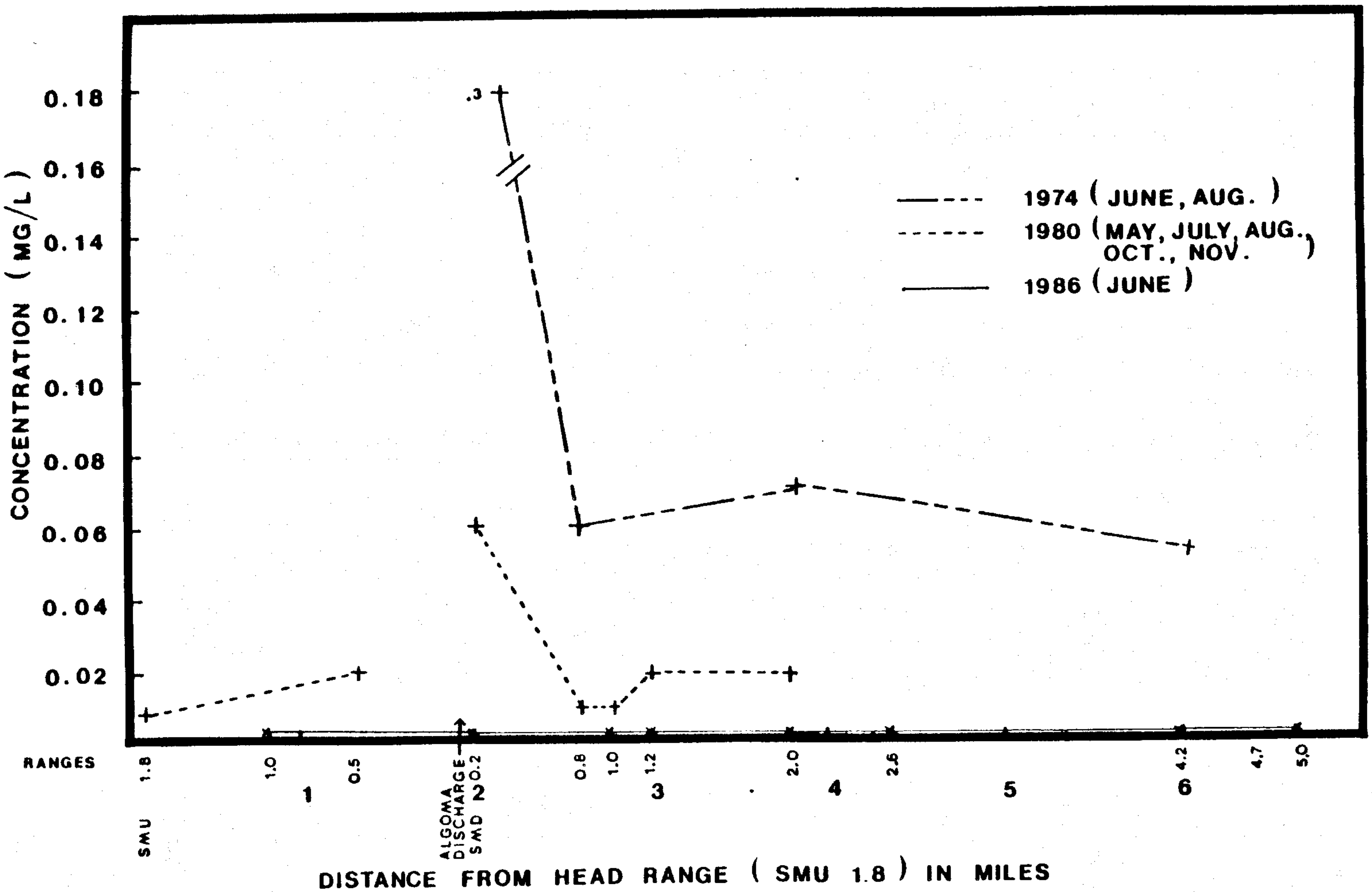

FIGURE VI-6. Cyanide distribution and yearly trends along the Canadian shore.

exceedence of the water quality objectives in 40 samples across the transect. In the Algoma Slip, iron exceeded the PWQO and GLWQA specific objective of 0.3 mg/L (average 0.445 mg/L with a maximum of 1.0 mg/L). All samples met the U.S.EPA chronic AWQC of 1 mg/L for chronic toxicity. Iron levels along the Michigan shoreline in 1986/87 ranged between .008 mg/L to 0.087 mg/L.

The elevated iron levels during the period 1970-74 decreased to levels in the range of 0.11 - 0.15 mg/L during the period 1976-1980 (10).

Total zinc levels in the St. Marys River along the Ontario and Michigan shorelines in 1986-87 displayed no distinctive longitudinal variations. Concentrations ranged between 0.001 and 0.009 mg/L, a decrease from 1980, when concentrations of 0.01 mg/L were prevalent. All these concentrations are below relevant water quality standards or guidelines.

Phosphorus:

In 1986-87, phosphorus levels along the Canadian shore ranged from 0.002 to 0.051 mg/L and from 0.005 to 0.014 mg/L along the Michigan shore. The highest level of phosphorus (0.051 mg/L) along the Canadian shore was noted just downstream of the Ontario Sault Ste. Marie East End WWTP (SMD 5.0). No elevated levels of phosphorus (relative to upstream levels) were noted downstream of the Sault Ste. Marie, Michigan waste water treatment plant (WWTP). Phosphorus levels were slightly higher along the U.S. and Canadian shores at Pointe Aux Pins (SMU 5.0) in 1986. The levels were 0.012 and 0.014 mg/L, respectively. However, all phosphorus levels in the St. Marys River met the PWQO of 0.03 mg/L with the exception of immediately downstream of the East End WWTP.

Polynuclear Aromatic Hydrocarbons (PAHs):

With the exception of polynuclear aromatic hydrocarbons (PAHs), trace organic contaminants such as chlorinated benzene and halogenated volatiles are not generally found in the St. Marys River. The environmental significance of PAHs in the St. Marys River cannot be determined due to the absence of surface and drinking water criteria for PAH compounds with the exception of the interim benzo(a)pyrene Ontario drinking water Maximum Acceptable Concentration (MAC) of 10 ng/L. For the maximum protection of human health from the potential carcinogenic effects of PAHs due to ingestion of contaminated aquatic organisms which may result in an incremental increase of cancer risk of 10^{-6} over a 70 year lifetime, a criterion of 31 ng/L for total PAHs was developed by the U.S.EPA (13). This is used as a yardstick to assess the significance of levels found in the St. Marys River.

Worldwide information on PAHs (14) indicates concentrations of benzo(a)pyrene range from approximately 0.1 to 100 ng/L. In Lake Erie, near Buffalo, Bass and Saxene (15) found 0.3 ng/L benzo(a)-pyrene and 4.7ng/L total PAHs. Williams et al. (16) extracted large volumes of municipal treated drinking water taken from 12 plants using Great Lakes water. The winter and summer concentrations (+/- 1 standard deviation) respectively were relatively high for pyrene (11.2 +/-20.0 and 3.9 +/- 10.2 ng/L) and fluoranthene (9.2 +/- 12.0 and 10.6 +/- 25.0 ng/L). Eadie (17) found 15 (+/- 9) ng/L of fluroanthene and 14 (+/- 6) ng/L of both pyrene and benzo(a)pyrene in filtered offshore waters of southern Lake Michigan. The concentration of these compounds on suspended particles was 2-4 ug/g. At a concentration of 1 mg/L of total suspended matter, greater than 75% of these PAHs were in the dissolved phase.

In 1985, large volume sampling was used to determine PAHs associated with the aqueous phase in the St. Marys river, focusing on the industrial and municipal areas of Sault Ste. Marie, Ontario (Table VI-2 and Figure VI-7). Total PAHs in samples taken from Leigh Bay (station #3) and off the Algoma Slag Site (station #4) were similar to the upstream background level of 4.0 ng/L (station #2).

Total PAH concentration increased downstream, reaching a peak concentration of 31.8 ng/L in the Algoma Slip. Benzo(a)-anthracene, which was absent in the upstream samples, was found at levels of 0.23 ng/L at Station #7 and 0.38 ng/L at Station #5. Benzo(a)pyrene was found only at station #5 (0.08 ng/L). Elevated total PAHs, relative to the upstream site, persisted downstream (station #10) at least 1km from the Terminal Basins' discharge. The PAH levels along the Michigan shore (3.2 - 3.6 ng/L) were similar to background concentrations (4.0 ng/L) indicating no transboundary pollution.

In order to provide insight into the partitioning of PAHs, concentrations in the whole water samples as well as those associated with the suspended particulates were determined as part of a centrifuge sampling program in 1986. Twelve stations along the St. Marys River from Leigh Bay to immediately downstream of the Sault Ste. Marie East End WWTP were sampled (Figure VI-8).

Oliver (18) found a significant correlation between octonol/water (K_{OW}) and organic carbon corrected partition coefficients (K_{OC}). Utilizing total organic carbon levels (Figure VI-9), suspended particulate levels (Figure VI-10), PAHs measured on suspended particulates (Table VI-3), and appropriate partition coefficients and assuming that equilibrium had been reached between the PAHs in the aqueous and particulate phases, estimates of both aqueous and whole water PAH concentrations were derived (Tables VI-4 and VI-5, respectively).

TABLE VI-2

PAHs associated with the aqueous phase from APLE sampling in the St. Marys River (1985).

	STATION									
PAHs (ng/L)	2	3	4	5	7	9	10	12	13	14
Phenanthrene	1.48	1.90	1.04	7.50	15.90	13.56	3.45	NA	1.51	1.82
Anthracene	0.18	0.29	0.06	0.88	1.70	1.86	0.36	NA	0.22	0.15
Fluoranthene	0.93	1.33	0.91	10.00	11.64	8.73	3.24	NA	1.33	0.94
Pyrene	0.26	0.40	0.15	1.30	1.59	1.57	0.54	NA	0.32	0.15
Benzo(a)anthracene	-	-	-	0.38	0.23	-	-	NA	-	-
Chrysene	-	0.2	-	0.34	0.33	-	-	NA	-	-
Benzo(b)fluoranthene	0.54	0.05	0.04	0.34	0.29	-	0.11	NA	0.06	0.05
Perylene	0.49	0.096	0.07	-	-	-	-	NA	-	-
Benzo(k)fluoranthene	-	-	-	0.20	-	-	0.07	NA	0.03	0.03
Benzo(a)pyrene	-	-	-	0.08	-	-	0.02	NA	0.02	-
Benzo(g,h,i)perylene	0.09	0.18	0.18	-	-	0.12	-	NA	0.05	0.03
Coronene	0.02	0.02	0.02	0.29	0.12	0.06	0.04	NA	0.02	0.02
TOTAL PAHs	3.99	4.46	2.47	21.31	31.8	25.9	7.83	NA	3.56	3.19

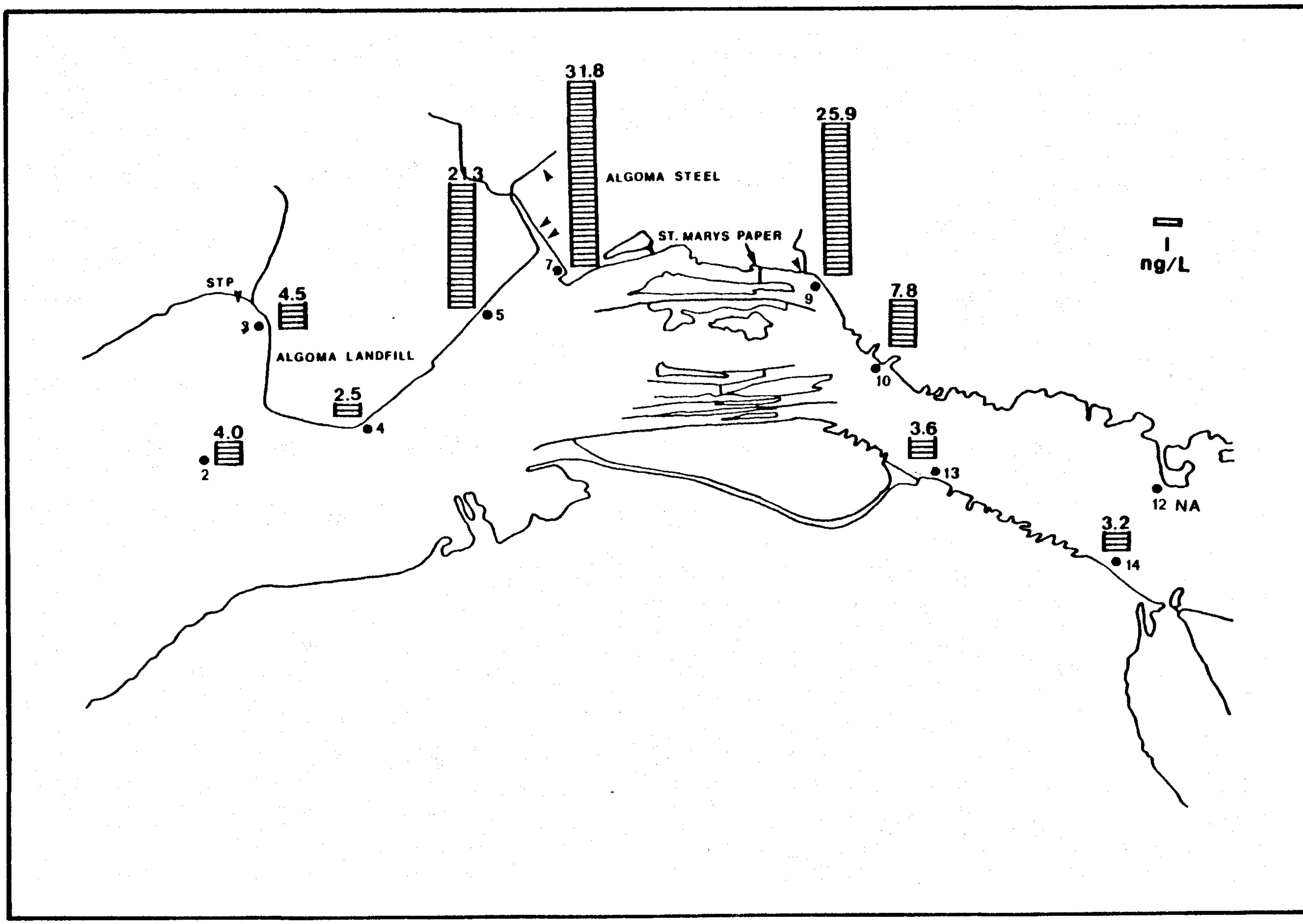

FIGURE VI-7. Total PAHs associated with the aqueous phase from APLE sampling (1985).

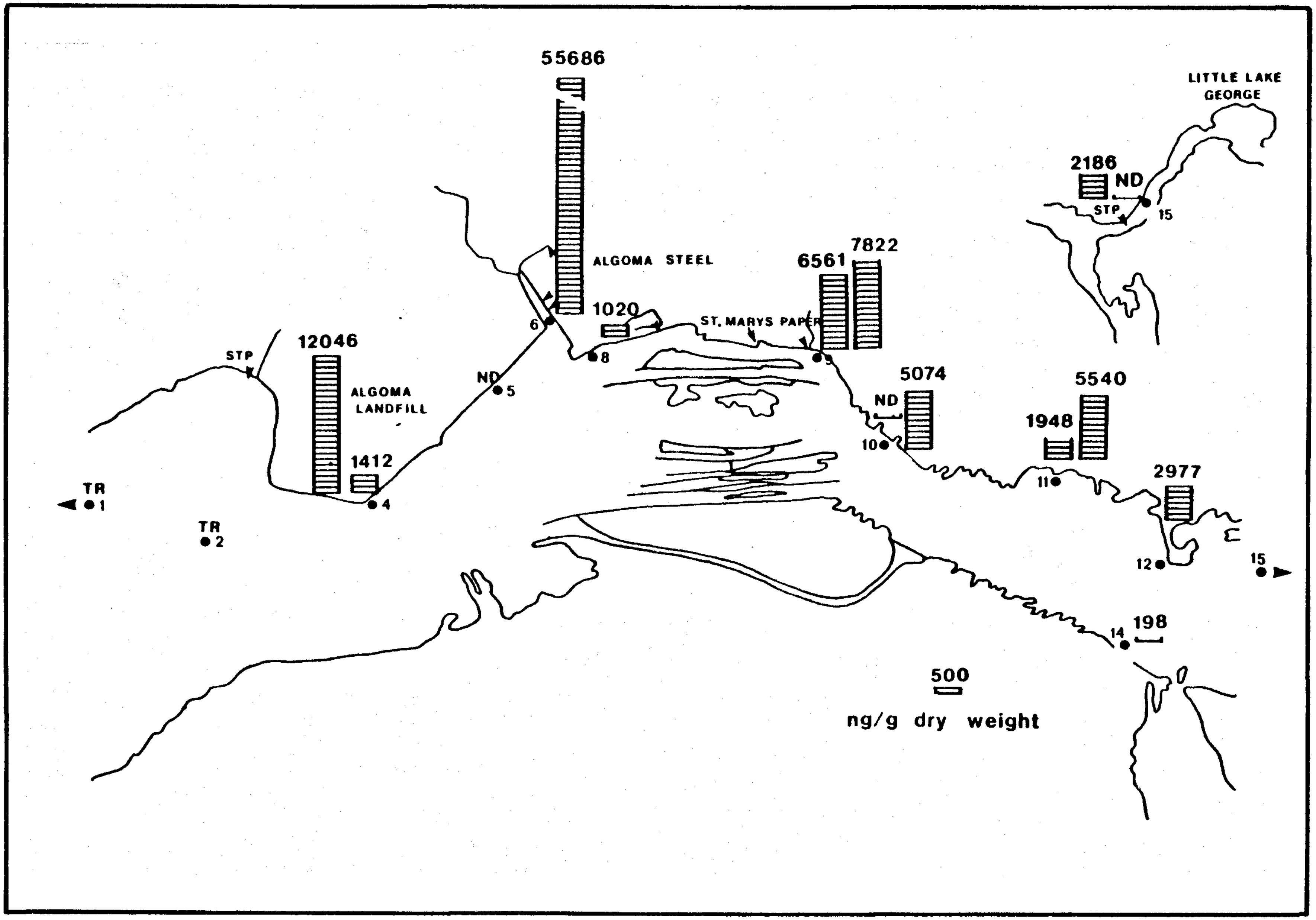

FIGURE VI-8. Total PAHs associated with centrifuged particulate matter (1986).

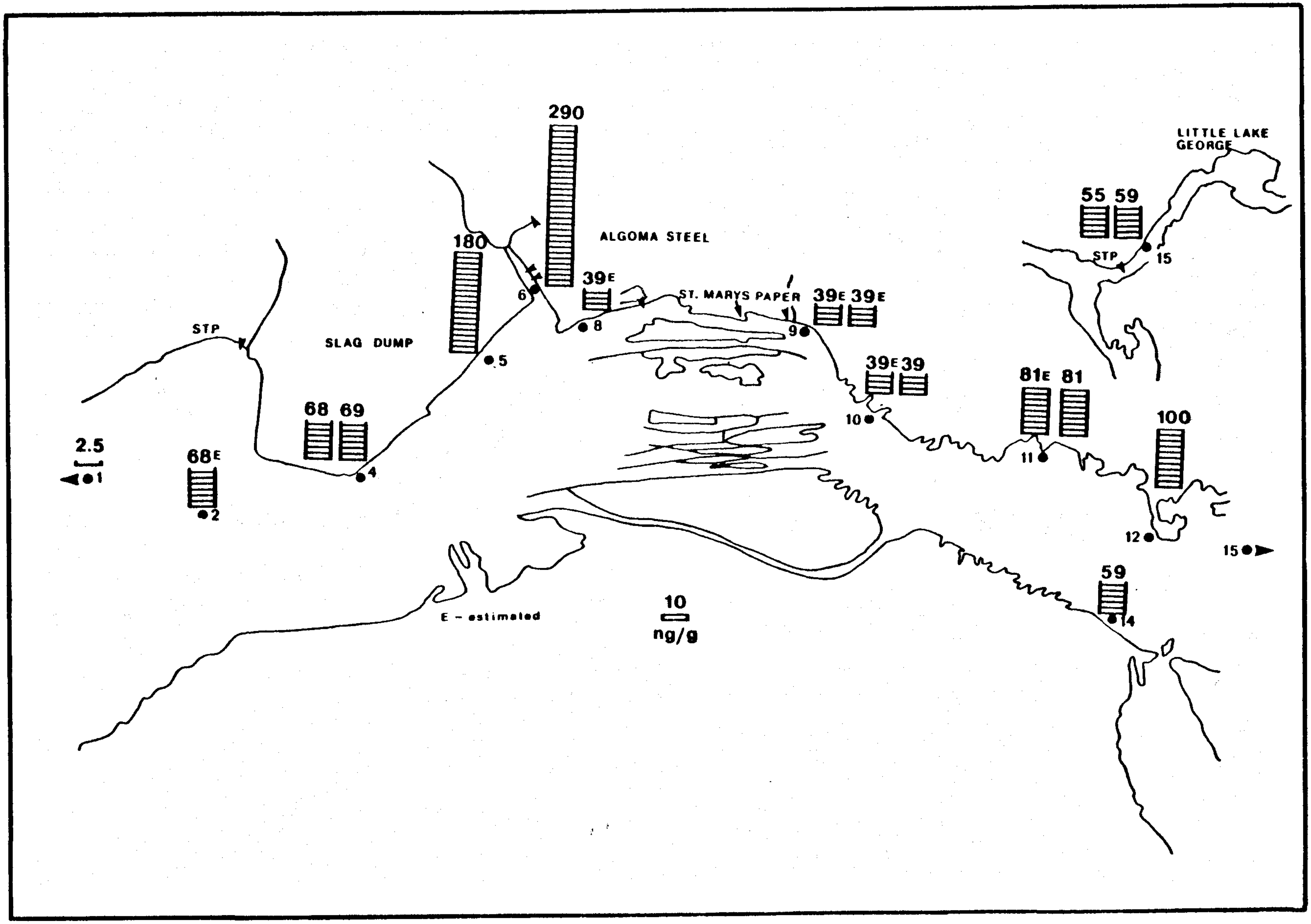

FIGURE VI-9. Total organic carbon levels in St. Marys River (1986).

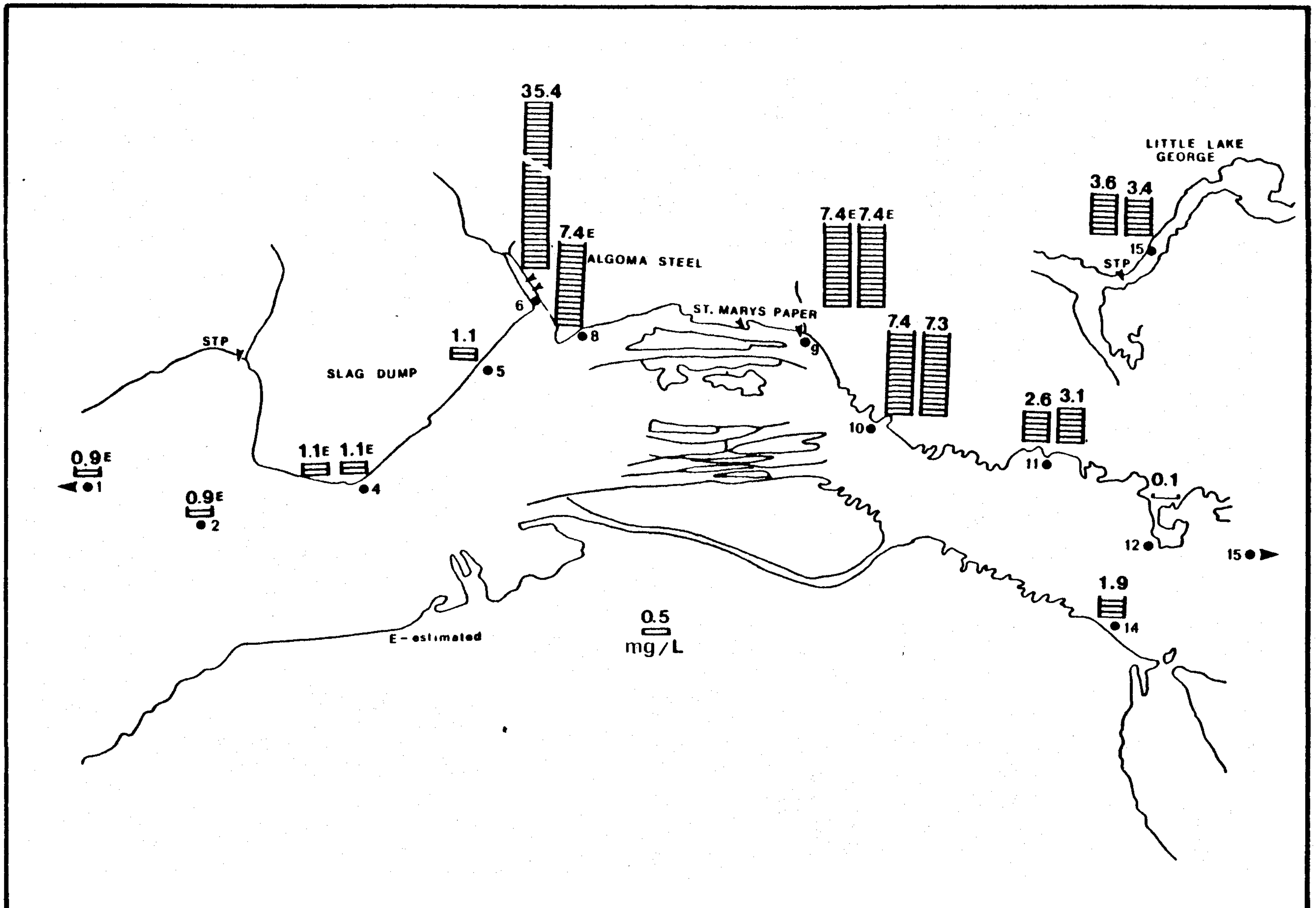

FIGURE VI-10. Suspended particulate levels in the St. Marys River (1986).

TABLE VI-3

PAHs associated with the centrifuged matter in the St. Marys River (1986).

PAHs (ng/g Dry Weight)	MDL ng/g)	STATION* 1	2 T	4 T	4 B	5 B	6 B	8 T	9 T	9 B	10 T	10 B	11 T	11 B	12 B	14 B	15 T	15 B
Naphthalene	50	ND	ND	ND	ND	ND	2,934	80	1,064	801	ND	ND	1,948	640	278	ND	184	ND
Acenaphthylene	50	ND	ND	ND	ND	ND	623	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	50	ND	ND	ND	ND	ND	1,086	TR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9 H Fluorene	60	ND	ND	ND	ND	ND	303	TR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	40	TR	ND	TR	189	ND	8,379	108	509	718	ND	ND	ND	447	ND	ND	189	ND
Anthracene	40	TR	ND	ND	ND	ND	2,444	120	ND	ND	ND	ND	ND	120	ND	ND	ND	ND
Fluoranthene	40	TR	ND	498	ND	ND	7,067	185	1,119	1,377	ND	1,358	ND	957	624	111	335	ND
Pyrene	40	TR	TR	479	290	ND	6,310	151	919	689	ND	1,262	ND	690	469	87	295	ND
Chrysene	50	TR	ND	7,995	233	ND	7,266	78	618	979	ND	TR	ND	538	362	ND	264	ND
Benzo(a)anthracene	50	TR	ND	1,337	286	ND	7,684	109	865	1,258	ND	1,035	ND	680	465	ND	408	ND
Benzo(a)pyrene	50		ND	593	ND	ND	3,882	67	465	650	ND	ND	ND	535	283	ND	ND	ND
Benzo(k) and Benzo(b)fluoranthene	50	TR	ND	1,144	330	ND	5,819	122	1,002	1,350	ND	1,419	ND	933	496	ND	511	ND
Dibenzo(a,h)anthracene	50		ND	ND	ND	ND	336	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	50		ND	TR	84	ND	822	TR	ND	TR	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	50		ND	ND	TR	ND	731	TR	ND	TR	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL PAHs		TR	TR	12,046	1,412	ND	55,686	1,020	6,561	7,822	ND	5,074	1,948	5,540	2,977	198	2,186	ND

ND - Not Detected, TR - Trace

* T - Sample taken 1.5 m below surface.
B - Sample taken 0.5 m off bottom.

TABLE VI-4

Estimated concentrations of PAHs associated with the aqueous phase in the St. Marys River (1986).

STATION*

PAHs (ng/L)	1	2	4		5	6	8	9		10		11		12	14	15	
		T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Naphthalene	NA	NA	NA	NA	NA	1,310.57	35.73	475.27	357.79	NA	NA	870.14	285.88	124.18	NA	82.19	NA
Acenaphthylene	NA	NA	NA	NA	NA	74.90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	NA	NA	50.80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9 H Fluorene	NA	NA	NA	NA	NA	22.98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	6.55	NA	290.53	3.74	17.61	24.90	NA	NA	NA	15.50	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA	86.72	4.26	NA	NA	NA	NA	NA	4.26	NA	NA	NA	NA
Fluoranthene	NA	NA	2.50	NA	NA	35.42	0.93	5.61	6.90	NA	6.81	NA	4.80	3.13	0.56	1.68	NA
Pyrene	NA	NA	3.02	1.83	NA	39.81	0.95	5.80	4.35	NA	7.96	NA	4.35	2.96	0.55	1.86	NA
Chrysene	NA	NA	17.90	0.52	NA	16.27	0.17	1.38	2.19	NA	NA	NA	1.20	0.8	NA	0.59	NA
Benzo(a)anthracene	NA	NA	2.38	0.51	NA	13.66	0.19	1.54	2.24	NA	1.84	NA	1.21	0.83	NA	0.73	NA
Benzo(a)pyrene	NA	NA	0.54	NA	NA	3.54	0.06	0.42	0.59	NA	NA	NA	0.49	0.26	NA	NA	NA
Benzo(k) & Benzo(b)fluoranthene	NA	NA	0.23	0.07	NA	1.16	0.02	0.20	0.27	NA	0.28	NA	0.19	0.10	NA	0.10	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	0.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	0.01	NA	0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-c,d)pyrene	NA	NA	NA	NA	NA	0.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL PAHs	NA	NA	26.57	9.49	NA	1,946.54	46.05	507.83	399.23	NA	16.89	870.14	317.88	132.27	1.11	87.15	NA

ND - Not Detected.
TR - Trace.
NA - Not applicable as PAHs were not detected on the centrifuged particulate matter (Table VI-3).

* T - Samples taken 1.5 m below surface.
B - Samples taken 0.5 m off bottom.

TABLE VI-5

Estimated concentrations of PAHs in whole water phase of the St. Marys River (1986).

PAHs (ng/L)	STATION 1	2 T	4 T	4 B	5 B	6 B	8 T	9 T	9 B	10 T	10 B	11 T	11 B	12 B	14 B	15 T	15 B
Naphthalene	NA	NA	NA	NA	NA	1,414.43	36.33	483.14	363.72	NA	NA	875.20	287.86	124.21	NA	82.85	NA
Acenaphthylene	NA	NA	NA	NA	NA	96.96	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	NA	NA	89.24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9 H Fluorene	NA	NA	NA	NA	NA	33.71	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	6.76	NA	587.15	4.54	21.37	30.21	NA	NA	NA	16.88	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA	173.23	5.15	NA	NA	NA	NA	NA	4.63	NA	NA	NA	NA
Fluoranthene	NA	NA	3.04	NA	NA	285.59	2.30	13.89	17.09	NA	16.72	NA	7.76	3.19	0.77	2.88	NA
Pyrene	NA	NA	3.55	2.15	NA	263.19	2.07	12.60	9.45	NA	17.18	NA	6.49	3.01	0.71	2.92	NA
Chrysene	NA	NA	26.69	0.78	NA	273.48	0.75	5.96	9.44	NA	NA	NA	2.87	0.85	NA	1.54	NA
Benzo(a)anthracene	NA	NA	3.85	0.82	NA	285.68	1.00	7.94	11.55	NA	9.40	NA	3.32	0.87	NA	1.54	NA
Benzo(a)pyrene	NA	NA	1.19	NA	NA	140.96	0.56	3.87	5.40	NA	NA	NA	2.15	0.29	NA	NA	NA
Benzo(k) & Benzo(b)fluoranthene	NA	NA	1.49	0.43	NA	207.15	0.93	7.61	10.26	NA	10.64	NA	3.08	0.15	NA	1.94	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	12.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	0.10	NA	29.15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2.3-c,d)pyrene	NA	NA	NA	NA	NA	0.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL PAHs	NA	NA	39.81	11.04	NA	3,891.94	53.63	556.38	457.12	NA	53.84	875.20	335.04	132.57	1.48	94.32	NA

T - Sample taken 1.5 m below surface
B - Sample taken 0.5 m off bottom
ND - Not detected
TR - Trace
NA - Not applicable as PAHs were not detected on the centrifuged particulate matter (Table VI-3)

Upstream samples (station #1 and #2) exhibited trace amounts of PAHs on the suspended particulates implying that PAHs may only be in the dissolved phase as found in 1985. In the vicinity of the Algoma Slag Site (station #4) the total PAHs associated with the suspended particulate amounted to 12,046 ng/g and 1,412 ng/g at 1.5 m below the surface and 0.5m off the bottom, respectively. These concentrations correspond to an aqueous phase having 27 ng/L and 9 ng/L in the water column, resulting in a whole water concentration of 40 ng/L. This level is above the criterion of 31 ng/L for total PAHs developed by U.S.EPA for the ingestion of aquatic organisms.

In a near-bottom sample from the Algoma Slip, in the vicinity of the 30" and 60" blast furnace sewer outfalls and downstream of East Davignon and Bennett Creeks, the total PAH concentration associated with the suspended particulate phase was 55,686 ng/g. This level, the highest observed in the study area, corresponded to an estimated whole water concentration of approximately 3,900 ng/L, greatly exceeding the U.S.EPA guideline for total PAHs of 31 ng/L. This high concentration may be related to both ongoing discharges as well as past losses, such as spills of coal tar.

At this location, measured concentrations for 12 PAH compounds in whole water (phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)-fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, dibenzo-(a,h)anthracene, and indeno(1,2,3,c,d)pyrene) ranged from 504 ng/L to 2,520 ng/L. The upper range of these measured concentrations is similar to the concentrations estimated from the levels associated with suspended particulates for the 12 PAHs (2,258 ng/L). The estimated and measured concentration of benzo(a)-pyrene in the whole water phase in the Algoma Slip locations exceed the interim Ontario drinking water MAC of 10 ng/L. There are no drinking water intakes downstream from the industrial discharges.

Immediately downstream of the Terminal Basins' discharge (station #9), total PAH concentrations associated with the suspended particulates at 1.5 m below the surface (6,561 ng/g) and 0.5 m off the bottom (7,822 ng/g) were similar due to vertical mixing. The estimated total PAH concentrations (naphthalene, phenanthrene, fluoranthene, pyrene, chrysene, benzo(a)pyrene, benzo(b,k)fluoranthene, and benzo(a)anthracene) associated with the aqueous phase were 508 ng/L and 399 ng/L in the samples taken at the surface and 0.5 m off bottom, respectively. The predicted total concentration for the 12 PAH compounds in the aqueous phase of surface water in 1986 was 33 ng/L. This was similar to the measured PAH concentration (same 12 compounds at station #6) of 26 ng/L in 1985. The estimated whole water total PAH concentrations were 556 ng/L and 457 ng/L in samples taken at 1.5 m below the surface and 0.5 m off the bottom, respectively. Both of these estimated levels exceed the U.S.EPA AWQC Human Health Criteria (fish consumption only) for total PAHs of 31 ng/L. The estimated concentration of benzo(a)pyrene associated with the whole water phase averaged 5 ng/L, lower than the interim Ontario MAC of 10 ng/L.

At station #11, located in a sheltered embayment, the total PAHs associated with the centrifuged particulate matter were much greater at the bottom than at the surface, reflecting the characteristics of depositional zone. Compounds attributable to industrial discharges were found in the sample taken 0.5 m off the bottom. The estimated concentration of total PAHs in the aqueous and whole water phases for this sample were 318 ng/L and 335 ng/L, respectively. This level greatly exceeds the U.S.EPA AWQC Human Health Criteria (for fish consumption) for total PAHs of 31 ng/L.

Generally, these elevated PAH levels associated with the suspended particulates persisted downstream of the Terminal Basin's discharge as far as the Sault Ste. Marie East End WWTP in Lake George Channel (Figure VI-8). At station #15, downstream from the Sault Ste. Marie East End WWTP the concentration of total PAHs associated with the suspended particulate matter at the surface was 2,186 ng/L. PAHs at 0.5 m off the bottom were not detected. This reflects the buoyant nature of the WWTP effluent. The estimated total PAHs associated with the whole water phase was 94 ng/L.

Along the U.S. shoreline, downstream of the Edison Sault Electric Company Canal, the concentration of total PAHs associated with the suspended particulates was 198 ng/g. The estimated concentration of total PAHs in the aqueous and whole water phases was 1.11 ng/L and 1.48 ng/L, respectively, considerably lower than levels identified along the Canadian shoreline.

Biota

The OMOE and the U.S. Fish and Wildlife Service (U.S.FWS) have monitored biota from various trophic levels in the St. Marys River since the early 1970s with the aim of defining the health of the river ecosystem. The St. Marys River Biota Workgroup Report synthesizes the published information together with the unpublished results of investigations conducted as part of the UGLCC Study (19,20,21).

i) Phytoplankton

Chlorophyll a showed very similar concentrations in the upstream and downstream reaches of the St. Marys River with a mean value of 0.78 mg/m^3 (4). Similarly, primary productivity studies using Carbon 14 techniques showed relatively low carbon assimilation, ranging from 5.5 to 57.9 mg $C/m^2/d$. Based on chlorophyll a concentrations, primary productivity and species composition (mainly diatoms) Liston et al. (4) concluded that the phytoplanton community of the river is similar to that of Lake Superior.

ii) Macrophytes and Macroalgae

Production:

Unpublished estimates of total primary production for the St. Marys River made by Duffy et al. (1) show the contribution of emergent plants (4,710 tonnes/yr), is about 20 times that of phytoplankton and periphyton combined but only about 3 times that contributed by submerged plants. Thus, the emergent and submerged plant communities are the major primary producers in the St. Marys River (1,20).

Biomass Drift:

Observations of plant detritus drift in the St. Marys River (1,21,22) indicated a general pattern. In the spring a pulse of plant detritus from the emergent wetlands and from the submerged plant communities further offshore is initially retained and utilized in-situ. Eventually, a portion of the detritus is dispersed to offshore and downstream areas by currents and wave action.

The living component of plant drift constitutes a small fraction of total plant biomass drift as compared to the detritus component. The total living plant biomass entering the St. Marys River from Whitefish Bay in April to October 1986 was approximately 1,555 tonnes wet weight and 77.7 tonnes ash-free dry weight. During the same time the combined total leaving the river through the St. Joseph Channel below Lake George and the outlet of Lake Munuscong was 10,362 tonnes wet and 518 tonnes ash-free dry weight (23).

The drift of detritus and living plant material may be an important mechanism for the redistribution of food resources within the river. However, the drift of plant material containing contaminants may also facilitate the dispersal of contaminants within the river and their transport from the river into Lake Huron.

iii) Benthic Invertebrates

The St. Marys River supports a diverse benthic invertebrate community composed of more than 300 taxa (1). Chironomidae and Oligochaeta are the most numerically abundant. The Ephemeroptera and particularly the burrowing mayflies (Hexagenia and Ephemera) are also abundant, and they may be the most important benthic invertebrates in the river because of their central role in trophic interactions. The Chironomidae are more strongly represented numerically in the upper and middle reaches of the river, while the Oligochaeta and Ephemeroptera are more abundant in the lower river (2,3,6,21,24). Overall, the abundance of benthic invertebrate is highest in the middle reaches of the river, and slightly higher near the head of the river near Whitefish Bay than in the lower reach near Lake Huron (1).

The benthic macroinvertebrate community of the St. Marys Rapids and Lake Nicolet Rapids (5,25) is typical of those found elsewhere in rapids or rocky streams and differs substantially from communities found in other portions of the river (1).

The navigation channels in the river are not intensively colonized by benthic invertebrates (1,2,4). Only Oligochaeta and Chironomidae are common in this habitat and both taxa generally occur only in low densities. Vessel induced turbulence and the removal of soft substrates by dredging are probably responsible for the poor benthic invertebrate community typically observed in the navigation channels.

Studies of impairment in the benthic communities in the St. Marys River were conducted in 1967 (26), 1973 (10), 1974 and 1975 (27), 1983 (28), and 1985 (29,30). Generally, zones with impaired benthic communities corresponded with the occurrence of visible oil and elevated levels of other contaminants in the sediment. Specifically, an inverse relationship between the abundance of Hexagenia nymphs and visible oil in the substrate was noted. Impact zones were restricted to the Ontario portion of the St. Marys River and were found immediately downstream of the discharges of Algoma Steel, St. Marys Paper, and the East End WWTP and in the depositional zones of Lake George. In Michigan waters and all portions of the river upstream of point source discharges, benthic communities were unimpaired. No impacts from transboundary transport of contaminants were apparent along the Michigan shoreline.

To better determine zones of impact, cluster analysis was performed on the 1985 data using various physical, chemical, and biological components of the benthic system (29). Seven major clusters were distinguished and four pollution impairment zones were identified.

1. SEVERE:

This zone is found in the Algoma Slip area and in embayments downstream from the industrial and municipal discharges along the Ontario shoreline of the river. This zone is characterized by extreme tubificid dominance (i.e., L. hoffmeisteri and immatures without capilliform chaetae), pollution tolerant chironomids, low numbers of taxa and high total densities, or communities with either very low total densities and low numbers of taxa, and/or high densities of nematodes with few other taxa.

2. MODERATE:

This zone, mainly confined to the Ontario shoreline, is approximately 500 m wide, extending 4 km downstream from the industrial and municipal discharges. Tubificid dominance with high densities of nematodes and facultative chironomids, absence of polychaete worms, reduced numbers of taxa and high total densities are the major characteristics of this zone.

3. SLIGHT:

Some recovery was apparent with increased distance from industrial and municipal discharges; however, complete recovery was not apparent until the lower section of Lake George. Nematode and polychaete dominate with moderate densities of tubificids and some nontolerant groups are present.

4. UNIMPAIRED:

This zone was found in the upper reaches of the river and along the Michigan side of the river. Communities tended towards chironomid dominance, with several nontolerant groups (e.g. Ephemeropterans and Trichopterans) present, together with low tubificid densities and high numbers of taxa.

The macroinvertebrate community impairment zones are summarized in Table VI-6 and illustrated in Figure VI-11. It is important to realize, however, that areas of the St. Marys River defined as "unimpaired" by benthic community structure analysis may nevertheless be unsuitable or "impaired" habitats to Hexagenia when oil is present even in a physically suitable substrate. This organism has a central role in the food webs.

Over the years only slight improvements have been noted in the benthic community in the Ontario waters of the St. Marys River.

Sediment Quality-Benthic Macroinvertebrate Contamination:

Persaud et al. (31) examined contaminant concentrations in benthic invertebrates and in corresponding sediments at four stations, located downstream of the discharges of Algoma Steel, St. Marys Paper and the East End WWTP (Figure VI-12).

The <63um size fraction of the sediments includes the very fine sand, silt and clay components. This size range is normally ingested by benthic invertebrates (32). Most chemical contaminants were associated with this fraction. Sequential chemical extractions on the <63um sediment identified six geochemical phases.

TABLE VI-6

Characteristics of benthic community zones in the St. Marys River (1985).

	ZONES			
	Unimpaired	Slight	Moderate	Severe
Common Taxa	Immat.Tubificids w/o chatae *Nematoda Procladius Bezzia *Manayunkia Spirosperma Cricoptopus Pisidium Chironomidae Polypedilum Chironomus Helisoma Amnicola limosa Hyallela Hydracarina Valvata sincera	*Immat.Tubificids w/o chaetae *Nematoda *Manayunkia Nemertea Stylodrilus Pisidium Spirosperma Immat.Tubificids with chaetae	*Immat.Tubificids w/o chaetae *Nematoda Nais variabilis	*Immat.Tubificids w/o chaetae *Nematoda *Chironomidae
Mean No. Taxa	27-40	23	15	12
Mean Total Density (No/m2)	56,000-201,000	192,000	259,000	71,000
Substrate	Variable Silty-Coarse Sand	Coarse Sand w or w/o Silt	Organic Silt	Silt
Water Depth(m)	1-13.7	2.5-14	1-16	1.5-8.5
Macrophytes	Variable	Absent or Sparse	Variable	Usually Absent
Visible Oil	Absent-Very Strong	Absent-Very Strong	Slight-Very Strong	Absent-Very Strong
Current	None-Moderate	Slight-Moderate	None	None-Strong

* Dominant Taxa

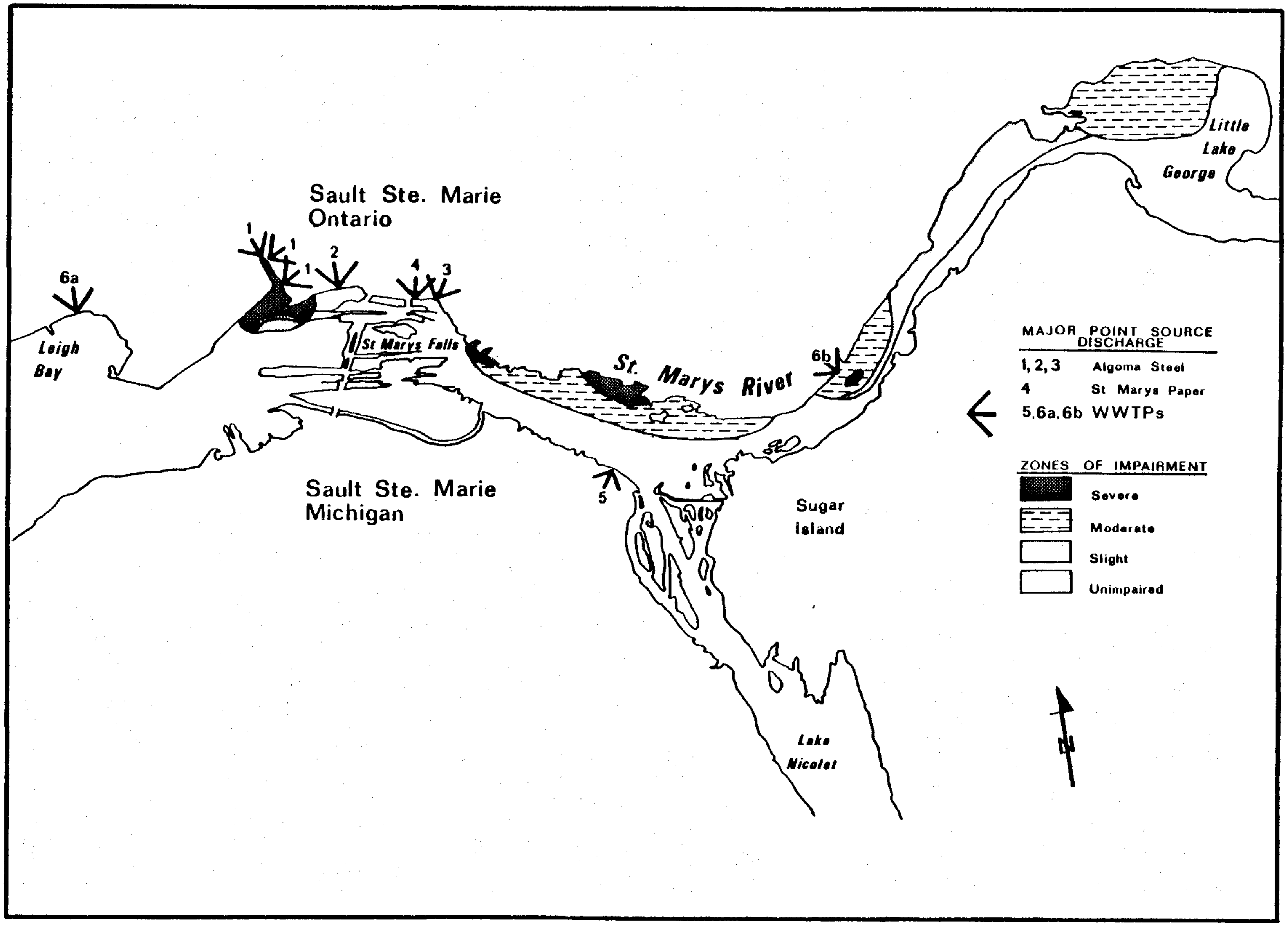

FIGURE VI-11. Distribution and zones of impairment of benthic fauna (1985).

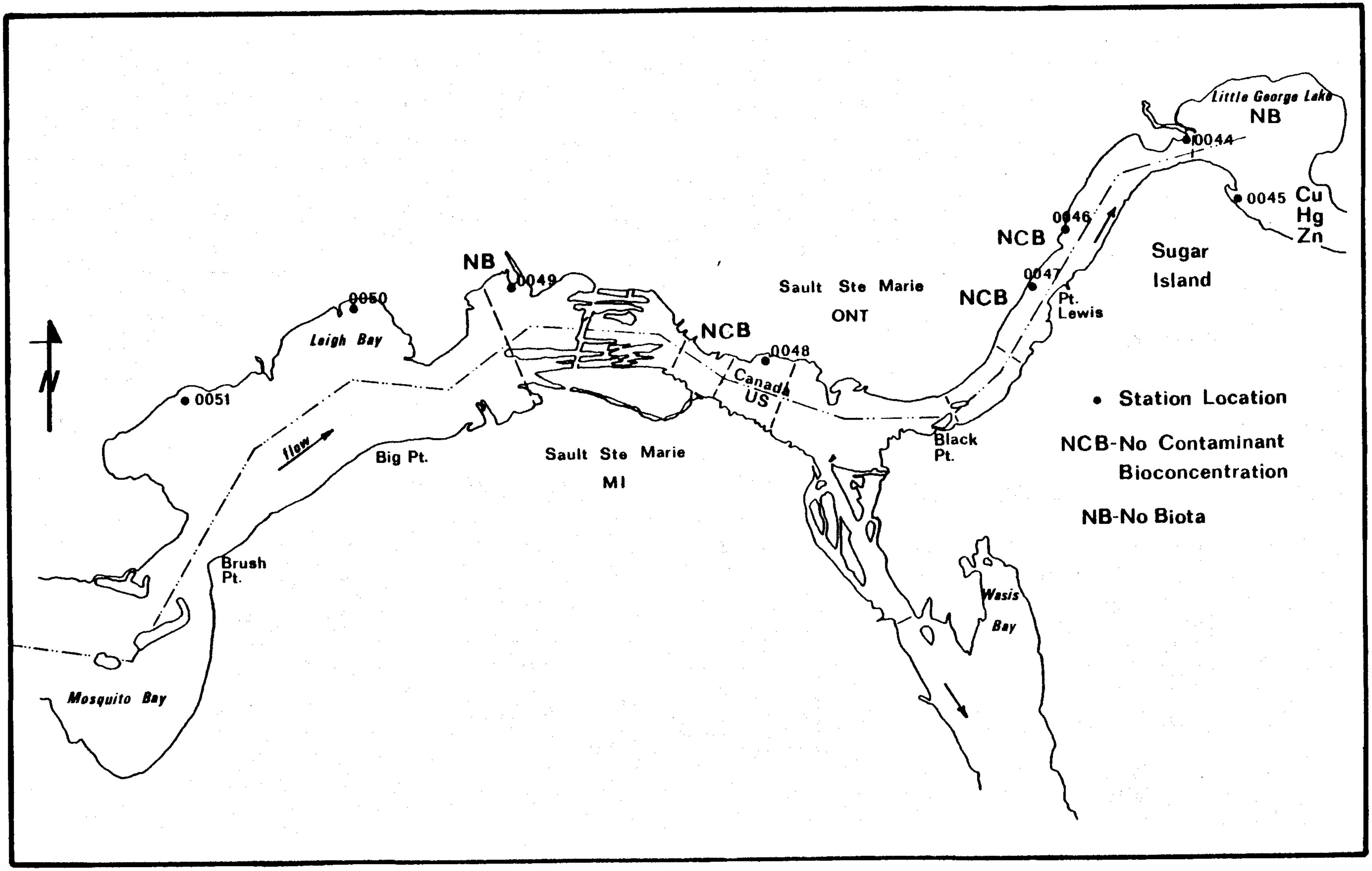

FIGURE VI-12. St. Marys River station locations and parameters showing bioconcentration factors greater than 1.0.

In the St. Marys River, 77% of the copper, 96% of the cadmium, 94% of the lead, 84% of the zinc, 23% of the manganese, and 12% of the iron was in potentially available forms. With the exception of Fe and Mn, most of the potentially available metals were associated with the organic/sulphide fraction. The largest fraction of Fe and Mn was held in the residual phase.

Table VI-7 shows the levels of metals in benthic tissue and sediment and the ratio of the tissue/sediment values referred to as bioconcentration factors. The sediment metal values used in these tables were the "available" metal concentrations obtained from the sequential extraction data. Bioconcentrations factors of copper, zinc and mercury were greater than one only at a station located in Little Lake George (station #45) which had the lowest bulk sediment contaminant levels. The uptake of these three metals was found to be inversely proportional to the organic matter content of sediments, especially the solvent extractables (oil and grease). In areas with high levels of organic matter, uptake was very low, despite the fact that the concentrations of metals were generally at their highest in the sediment. Also, copper and zinc concentrations in organisms appeared to be related to specific geochemical fractions.

These data show that contaminated sediments can be a source of contaminants to benthic organisms. The high levels of contamination and the concentration of certain contaminants in the tissue of these organisms raises concerns related to the potential for transfer of these contaminants to higher organisms that feed on these species. Toxic effects could also result in the complete elimination of benthic organisms or reduction in species diversity and individuals to a few tolerant organisms.

Recently, increased emphasis has been placed on determining the concentrations, distribution and availability to biota of polynuclear aromatic hydrocarbons (PAHs) in river water. In 1985 uncontaminated clams were exposed in cages along the nearshore of the St. Marys River for three weeks. Clams placed in areas downstream from the Canadian discharges accumulated significantly higher levels of PAHs than clams exposed at the upstream locations (Figure VI-13). PAHs accumulated in clams exposed along the U.S. shoreline, but generally at lower levels than along the Canadian shoreline. Caged clams introduced in the Algoma Steel Slip accumulated the highest levels of total PAHs. The degree of accumulation of compounds in decreasing order of magnitude in the Slip were: phenanthrene; fluoranthene; pyrene; acenaphthene; fluorene; naphthalene; anthracene; chrysene/benzo(a)anthracene; and benzo(a)pyrene. Benzo(a)pyrene in clams was well below the proposed IJC objective (33) of 1 ug/g for organisms serving as a food source for fish.(34)

TABLE VI-7

Concentrations of metals in sediment (ppm dry weight) and in benthic tissue (ppm dry weight, gut corrected) and corresponding bioconcentration factors in the St. Marys River.

SAMPLING STATION	COPPER			ZINC			LEAD			CADMIUM		
	S	BT	BCF	S	BT	BCF	S	BT	BCF	S	BT	BCF
45	23.1	22.5	1.0	118.7*	131.3	1.1	54.4*	2.4	0.0	1.0	0.3	0.3
46	166.9*	24.0	0.1	730.3*	115.8	0.2	217.4*	0.2	0.0	3.5*	0.3	0.1
47	89.4*	11.4	0.1	493.8*	107.5	0.2	157.1*	1.2	0.0	2.0*	0.3	0.2
48	168.1*	17.0	0.1	947.3*	110.7	0.1	619.3*	6.8	0.0	4.5*	0.3	0.1

SAMPLING STATION	IRON			MANGANESE			MERCURY			ARSENIC		
	S	BT	BCF	S	BT	BCF	S	BT	BCF	S	BT	BCF
45	6,272.3	1,030.2	0.2	64.9	39.6	0.6	0.1	0.5	5.0	NA	NA	NA
46	15,043.8	258.2	0.0	197.1	12.0	0.1	0.6	0.3	0.5	34.3	18.0	0.5
47	8,949.2	715.1	0.1	128.0	8.5	0.1	0.4	0.1	0.3	NA	NA	NA
48	13,280.3	104.2	0.0	362.4	-1.2**	0.0	0.6	0.0	0.0	NA	NA	NA

S = Sediment, BT = Benthic Tissue, BCF = Bioconcentration Factor, NA = Data Not Available

* Exceedes OMOE guidelines for the open water disposal of dredged materials.
** Negative values are the result of extremely low levels of Mn in benthic tissue compared with sediment values.

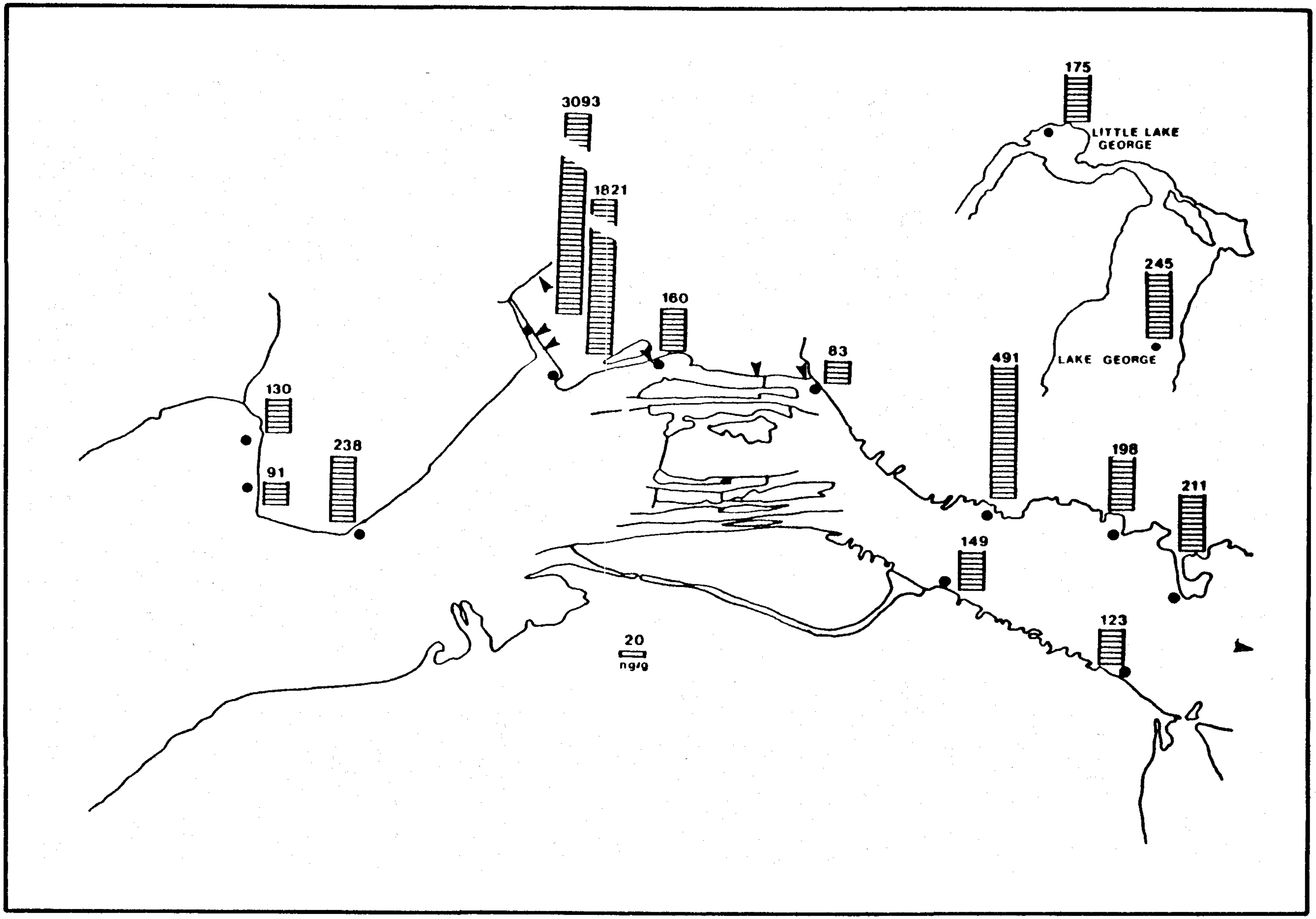

FIGURE VI-13. Total PAH concentrations (ng/g) in caged clams (Elliptio complanata)(1985).

iv) Contaminants in Fish

Sport fish in Ontario waters of the river are tested regularly by the OMOE for dorsal fillet concentrations of selected contaminants (mercury, PCBs, mirex, organochlorine pesticides, and 2,3,7,8-TCDD). As shown in Table VI-8, dieldrin, heptachlor, mirex and 2,3,7,8-TCDD were not detected in any fish samples. PCBs, DDT and lindane were below consumption guidelines. Concentrations of chlordanes, hexachlorobenzene and octachlorostyrene were also low, but there are no guidelines for these parameters.

Only mercury is found in fish in excess of the Canadian federal government guideline for fish consumption in the St. Marys River. Usually, only large specimens of certain species of sportfish contained sufficient mercury to warrant the Ontario government to issue consumption advisories (Table VI-9). There were no fish comsumption advisories issued by the Michigan Department of Public Health for 1988. Data for trend purposes are limited and indicate that trends in mean concentrations of mercury in walleye and northern pike since 1977 are not significant. Mean concentrations of mercury in rainbow trout declined by about 60% between 1978 and 1985.

Young-of-the-year yellow perch collected near Sault Ste. Marie, Ontario contained PCBs, but these concentrations (average 25 ppb) were well below the GLWQA specific objective (100 ppb) for the protection of birds and animals which consume fish (35) and the Ontario and Michigan fish consumption guidelines. No detectable levels of chlorophenols or chlorinated aromatics were found in these fish. Preliminary analysis of whole fish (36) indicate that white sucker and brown bullhead from the North Channel of Lake Huron contained detectable levels of naphthalene, acenaphythylene, acenaphthene, phenanthrene, anthracene, fluoranthene and pyrene. These concentrations were similar to those found in these species from other industrialized areas of the Great Lakes, such as Hamilton Harbour and the St. Lawrence River.

v) Contaminants in Birds

The early 1980s saw a marked resurgence in the number of young produced per active nest of both ospreys and bald eagles. In 1986 and 1987, bald eagles successfully nested on the Munuscong Lake shoreline and produced two young each year.

Limited data are available for current contaminant levels in birds. Monitoring has generally been limited to eggs, owing to the susceptibility of embryos to the effects of toxic organic compounds which bioaccumulate. Common tern eggs that were collected in 1984 from Lime Island had very low or undetectable concentrations of organochlorine compounds (U.S.FWS, unpublished data). The exceptions were p,p-DDE and PCBs. The mean DDE concentrations in 10 eggs was 1.8 ug/g and for PCBs, 0.9 ug/g.

TABLE VI-8

Contaminants in dorsal fillets of sport fish from Ontario waters of the St. Marys River.

Contaminant	Concentration (ppm wet wt.)	
	Consumption Guideline*	Observed Range
Mercury	0.5	0.4-1.30
PCBs	2.0	ND-1.260
Chlordanes (Alpha & Gamma)	NA	ND-0.045
Dieldrin	0.3	ND
DDT and metabolites	5.0	ND-0.486
Heptachlor	0.3	ND
Endrin	0.3	NA
Lindane (Gamma-BHC)	0.3	ND-0.001
Mirex	0.1	ND
Hexachlorobenzene	NA	ND-0.011
Octachlorostyrene	NA	ND-0.009
2,3,7,8-TCDD	0.000020	ND

ND-Not Detected NA-No Data Available

Note: * Health and Welfare Canada guidelines and Great Lakes Quality Agreement specific objectives for the protection of human consumers of fish.

Ontario Ministry of the Environment (OMOE) data (A. Johnson pers. comm.) for individual dorsal fillets of various species collected from the St. Marys River below the rapids, Lake George, St. Joseph Channel and St. Joseph Island since 1982.

TABLE VI-9

Species of sportfish from Ontario waters of the St. Marys River with fillet concentrations of mercury in excess of the Canadian Government Guideline for Fish Consumption (0.5 ppm).

Location	Species*	Size	Hg Concentration Range (ppm)
St. Marys R. (below rapids)	White Sucker	>35 cm	0.5 - 1.0
	Longnose Sucker	>30 cm	0.5 - 1.0
	Walleye	>45 cm	0.5 - 1.0
Lake George	Northern Pike	>65 cm	0.5 - 1.0
	Lake Trout	>55 cm	0.5 - 1.0
	Walleye	45-55 cm	0.5 - 1.0
	Walleye	>55 cm	1.0 - 1.5
St. Joseph Channel	Northern Pike	>75 cm	0.5 - 1.0
St. Joseph Island	Walleye	45-55 cm	0.5 - 1.0

* from "The 1988 Guide to Eating Ontario Sport Fish" (34).

The highest PCB concentration was 7.3 ug/g, a level which could have subtle intrinsic (to the egg) and extrinsic effects in terns. Mercury and selenium levels were not above reasonable background levels reported in bird eggs.

The Canadian Wildlife Service collected herring gull eggs from Pumpkin Point in 1985 and 1986. Only DDE and PCBs exceeded 1 ug/g in 10 egg composite samples, (Dr.C. Weseloh, personal communication). PCBs had the highest concentration, 22 ug/g, in 1985 and 14 ug/g in 1986. Although this is below the perceived toxicological threshold for herring gulls, it is important to recognize that a resistant species with a relatively high body (or egg) burden can be a source of significant contamination if consumed by other predators, such as raptors or mammals.

The concentration of 2,3,7,8-TCDD was also measured in herring gull eggs. Levels were considered in the background range at 4 pg/g in 1985 and slightly above background at 16 pg/g in 1986. Other dioxin-like compounds, including the highly toxic, non-ortho PCB congeners were detected in bullheads and walleye from the St. Marys River in 1984 (U.S.FWS, unpublished data). It is thought that these dioxin-like PCB congeners account for the majority of toxic effects in Green Bay Forster terns (37). Bird samples collected from the St. Marys River have not been analyzed for these congeners.

Bottom Sediments

i) Physical Characteristics

Physical characteristics of sediment samples taken during 1985 from the St. Marys River (38) indicated that sediment composition was strongly related to flow velocities. Sediment composition varied across the river according to the flow distribution. Upstream from the Sault locks, medium and fine sand constituted 80% of the particles. This sediment texture is attributed to the high river velocities in the channel where coarse material settled first and fine materials (silt and clay) remained in suspension and settled in embayments along the Ontario shoreline of the river.

A typical sediment composition from below the rapids at transect SMD 2.6, 4 km downstream of the Algoma Steel discharges is illustrated in Figure VI-14. The Michigan shoreline is characterized mainly by coarse and medium sand which represents about 63% of the sediment composition. Along the Ontario shoreline, where several embayments exist, the sediment is composed of silt (82%). In the mid-river, fine and very fine sand and silt constituted about 90% of the sediment composition. This particle sorting is attributed to the river flow distribution in the lower river where 69% of the total river flow is along the Michigan

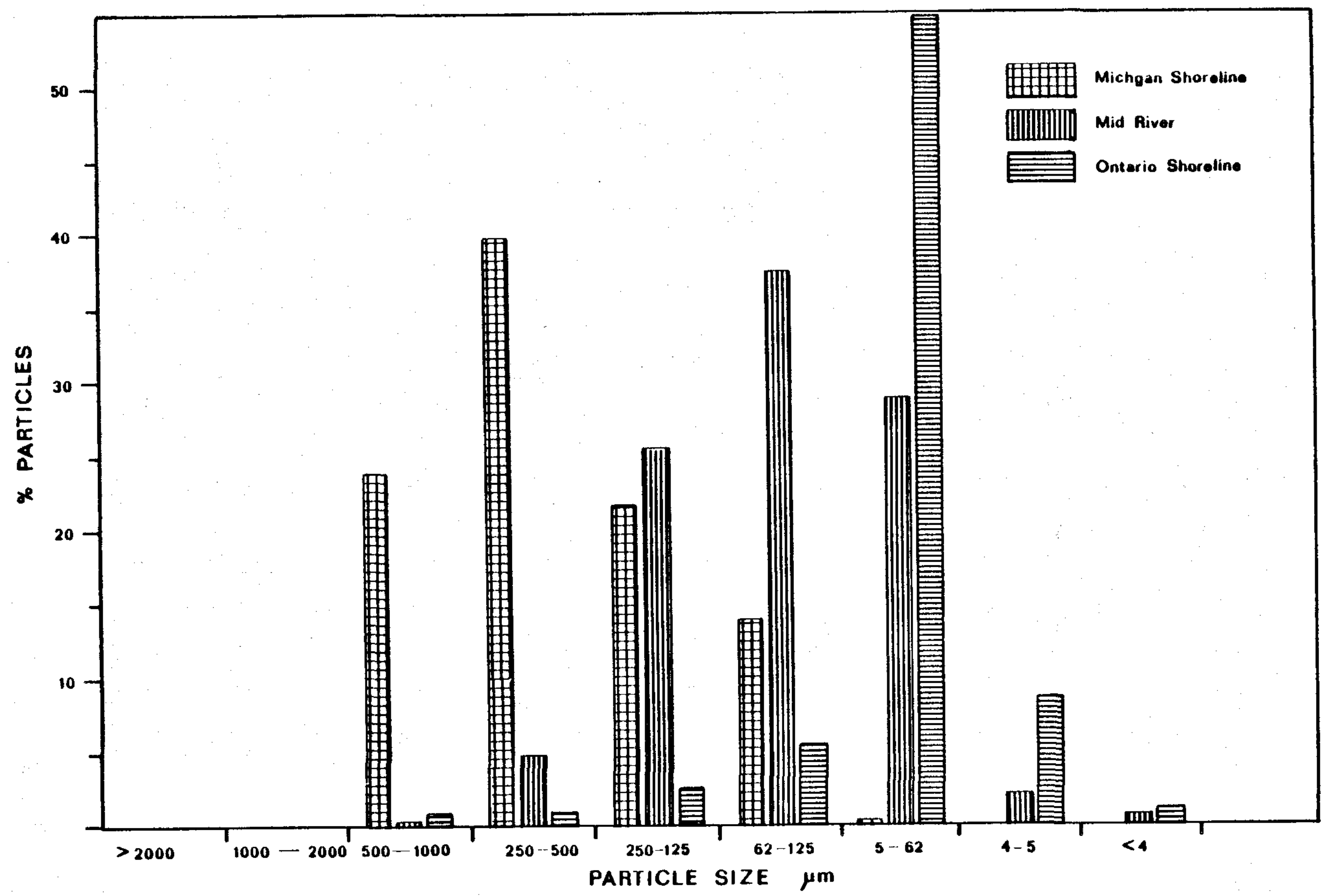

FIGURE VI-14. St. Marys River typical particle size.

shoreline and 31% is along the Ontario side.

ii) Sediment Transport

No bedload transport study was conducted in the St. Marys River. However, sedimentation rates were determined using Cs-137 measurements on two 1985 core samples from Lake George (OMOE stations #100 and 102). The peak of radionuclide Cs-137 occurred at approximately the 15 cm sediment depth in Lake George (Figure VI-15). The testing of large-scale nuclear weapons in the northern hemisphere started in 1954, increased significantly around 1958-59, and peaked during 1962-64. Since then the fallout of debris has decreased markedly. Consequently, in the dating of the sediment, the peak of Cs-137 is referred to the 1962-64 fallout peak activity of the atmospheric testing. This would correspond to a sedimentation rate of 0.22 $g/cm^2/yr$ (0.7 cm/yr) and 0.19 $g/cm^2/yr$ (0.53 cm/yr), or an average of 0.6 cm/yr. Results for sediment mixing for the two samples were 1.3 g/cm^2 (4.7 cm) and 1.7 g/cm^2 (5.8 cm).

In 1986 a joint U.S.EPA and OMOE seismic survey was conducted in portions of the St. Marys River including Lake George and Little Lake George. Preliminary seismic data indicate that the combined thickness of glacial deposits and unconsolidated sediments overlying bedrock exceeds 30 m in Lake George. The thickness of recently deposited sediment in this lake is in the order of 1 m. The data indicate that Little Lake George is also an active depositional area. There is about 0.3 m of sediment over bedrock and glacial deposits.

iii) History of Contamination

The concentrations of PCBs and DDT in the Lake George core taken in 1986 at station #102 are shown in Figure VI-16 (39) together with sediment dates estimated from the Cs-137 profile. The production of PCBs in the United States began in 1929 and peaked in 1970. In the core samples, PCBs are first detected in the segment corresponding to the 1950s and reach their maximum concentration in the early to mid-1970s. DDT usage in the U.S. began in 1944, peaked in 1959, and was banned in 1971. DDT first appears in the mid-1950s part of the core and reached its highest concentration in the early to mid-1960s. The peak concentration of PCBs and DDT in the core occurred approximately 5 years after peak production or usage of the chemicals. The major sources of PCBs and DDT in the area are likely remote and nonpoint, thus, time delays in their transfer to the St. Marys River sediment are likely. The low concentrations of these contaminants in the cores is further support for diffuse remote sources.

The concentration of total PAHs, particularly the PAH, benzo(a)-pyrene, in the sediment core are plotted versus depth and date in Figure VI-17. The PAH concentrations are three orders-of-mag-

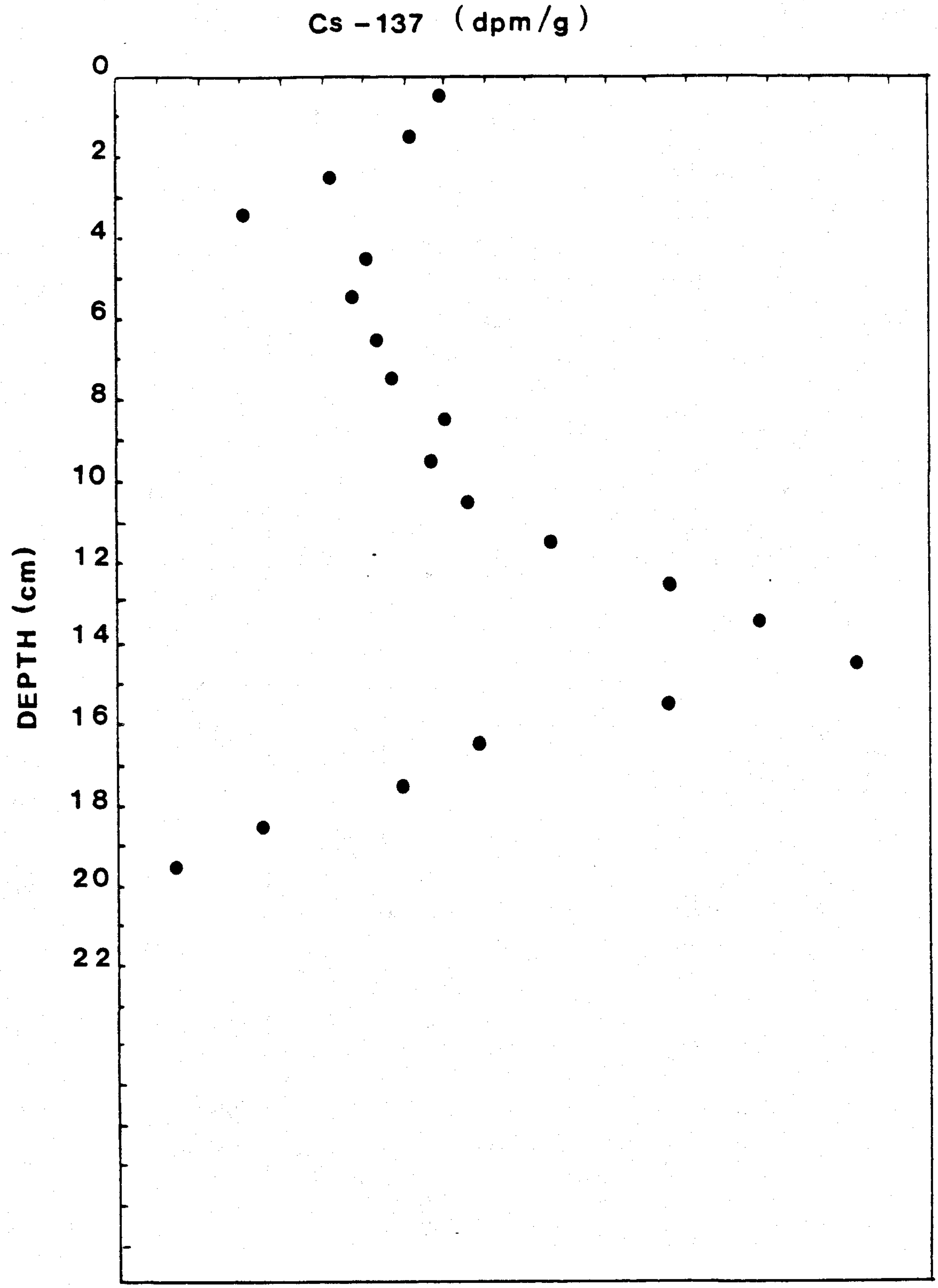

FIGURE VI-15. Variation with depth of ^{137}Cs in Lake George sediments.

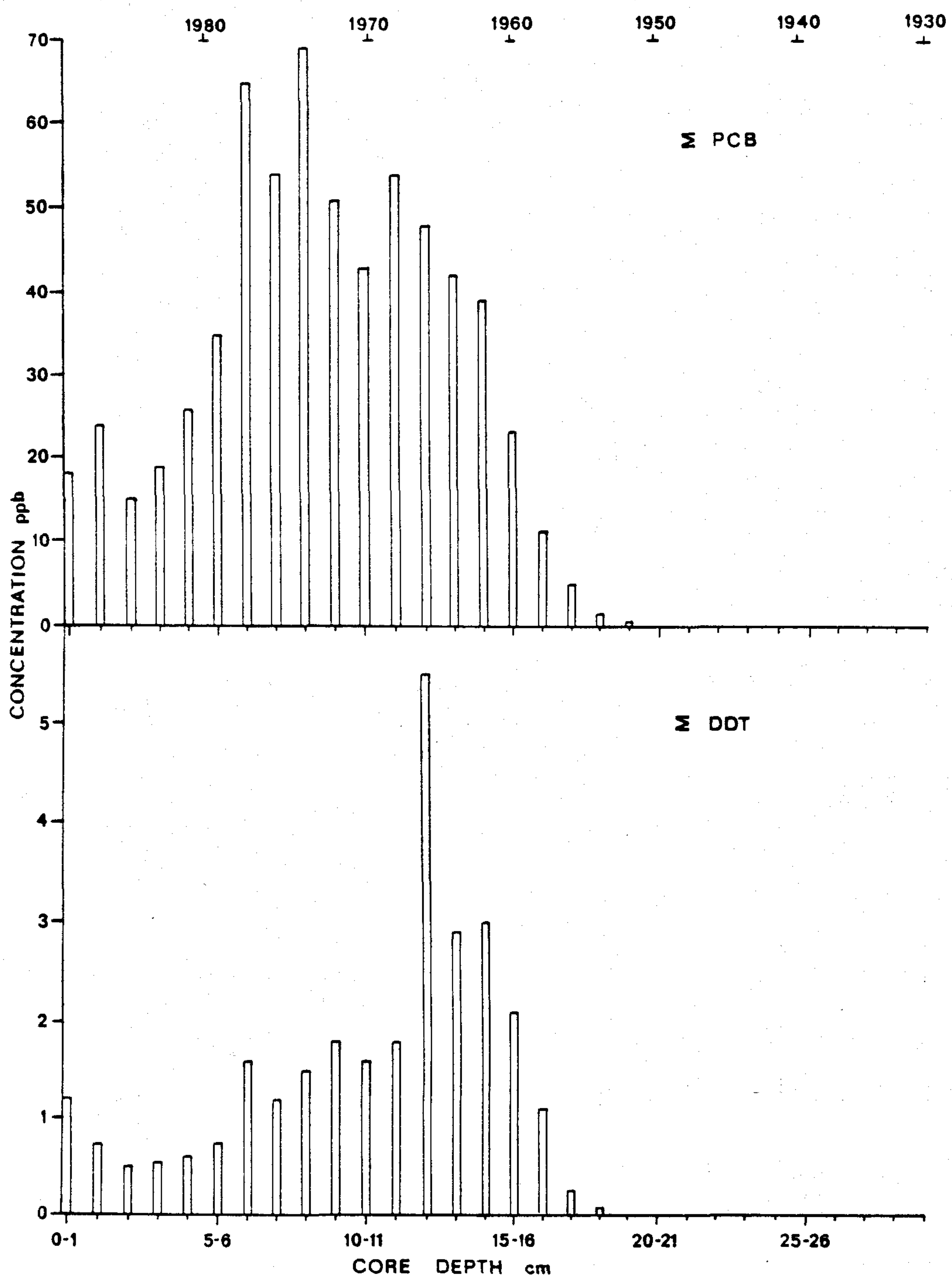

FIGURE VI-16. Total PCBs and DDTs in Lake George sediments (station 102, 1986).

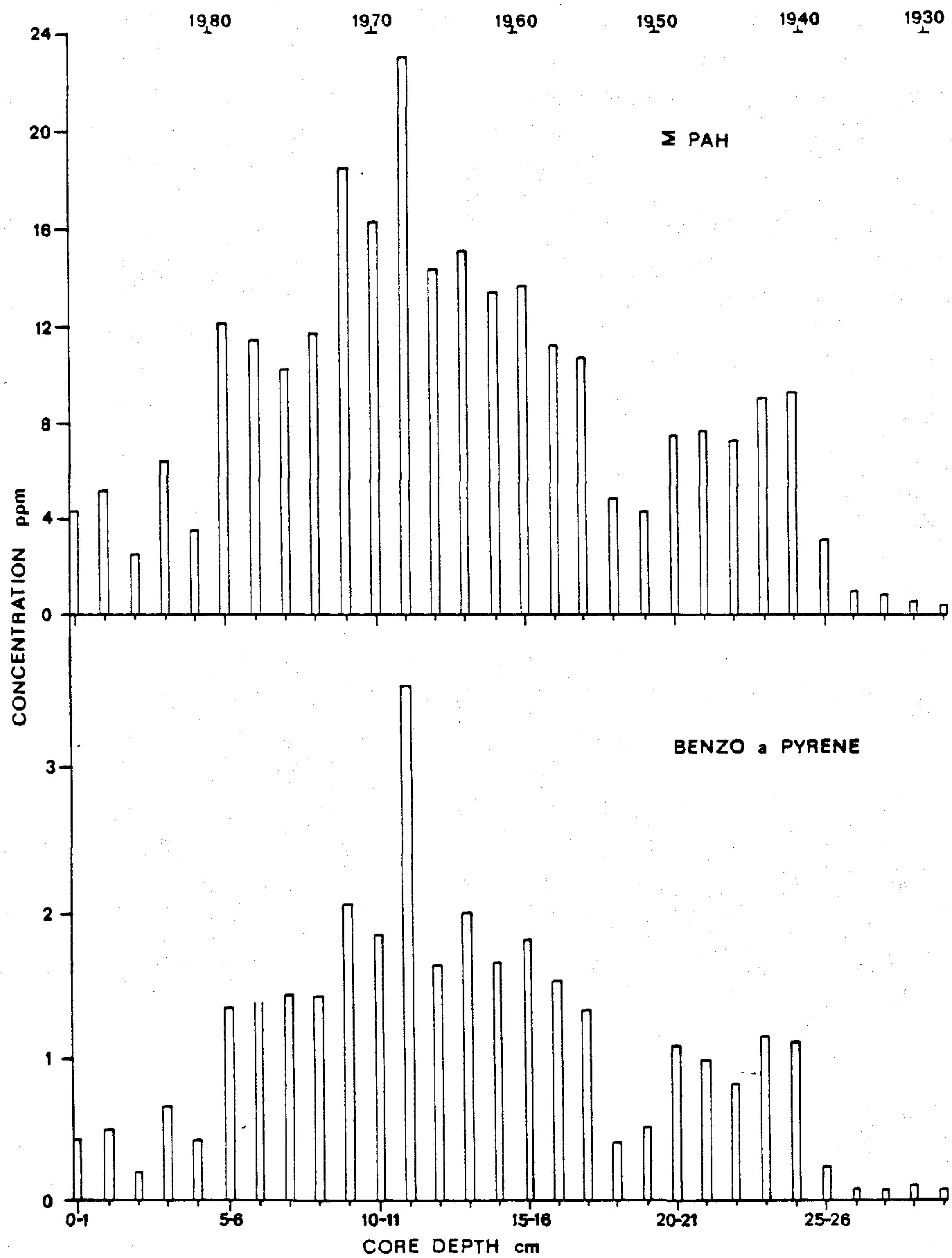

FIGURE VI-17. Total PAH and benzo(a)pyrene in Lake George sediments (station 102, 1986), core depth related to year by ^{137}Cs dating.

nitude higher (ppm versus ppb) than those of the chlorinated organics, indicating major PAH sources in the area. The Algoma Steel Mill in Sault Ste. Marie is likely the principal source of these chemicals to the river, because PAHs are known to be by-products of the coking process. Virtually the same concentration profile was found for total PAHs and for benzo(a)pyrene. The core concentration profile shows that PAH discharges in the area increased substantially in the early 1940s, probably due to increased steel production during World War II. A small lag in steel production occurred in the late 1940s to early 1950s, followed by a sharp increase in the late 1950s, peaking during the late 1960s or early 1970s. The pattern of PAH concentrations in the core segments is in excellent agreement with historical steel production in the area. Much lower concentrations of PAHs are found in the more recent sediments. This is probably due to a combination of lower steel production and improved pollution control.

Changes occurring in the relative distribution of PAH compounds at various core depths are illustrated in Figure VI-18. At a depth of 29-30 cm, corresponding to about 1930, indeno-(1,2,3,c,d)pyrene and benzo(g,h,i)perylene were the major PAHs in the sediment. Benzo(a)pyrene was below the detection limit at this core depth. During the peak of industrialization (1968, 11-12 cm) benzo(a)pyrene was the most dominant PAH but the other 4 and 5-ringed PAHs, pyrene, benzo(a)anthracene, chrysene, benzo-(b)fluoranthene and benzo(k)fluoranthene were also present at high concentrations relative to the other PAHs. In recent surficial sediments (0-10 cm, 1968) naphthalene and phenanthrene represent a significant fraction of the total PAHs, together with the 4- and 5-ringed PAHs. The concentrations of naphthalene and phenanthrene in the core are much less variable than benzo(a)-pyrene, indicating that they may originate from a different source.

Results for heavy metals in the core from Lake George (OMOE station #102) are presented in Table VI-10 (40). Only the first 20 cm of the core were analyzed. Distributions of Ni, Co, V and Cu were relatively uniform with depth but Zn, Pb and Cr were not. Zinc increased gradually from 185 to 410 ug/g between 4 and 12 cm and then decreased back to 139 ug/g at 20 cm depth (Figure VI-19). Lead peaked at 94 ug/g in the 10-11 cm segment and decreased to 39 ug/g at 20 cm of depth. Chromium peaked at 189 ug/g in the 15-16 cm section. Using the estimated sedimentation rate of 0.7 cm/yr for this sample, zinc, lead and chromium reached peak concentrations in the river around 1968-70.

The distribution of oil and grease in the core (Figure VI-19) was different than for total PAHs and zinc. Oil and grease increased gradually from 2,700 to 3,580 ug/g between 0 and 7 cm depth, increased drastically to 8,190 ug/g in the 7 to 8 cm segment (mid-1970s) and then decreased gradually to 360 ug/g at 30 cm.

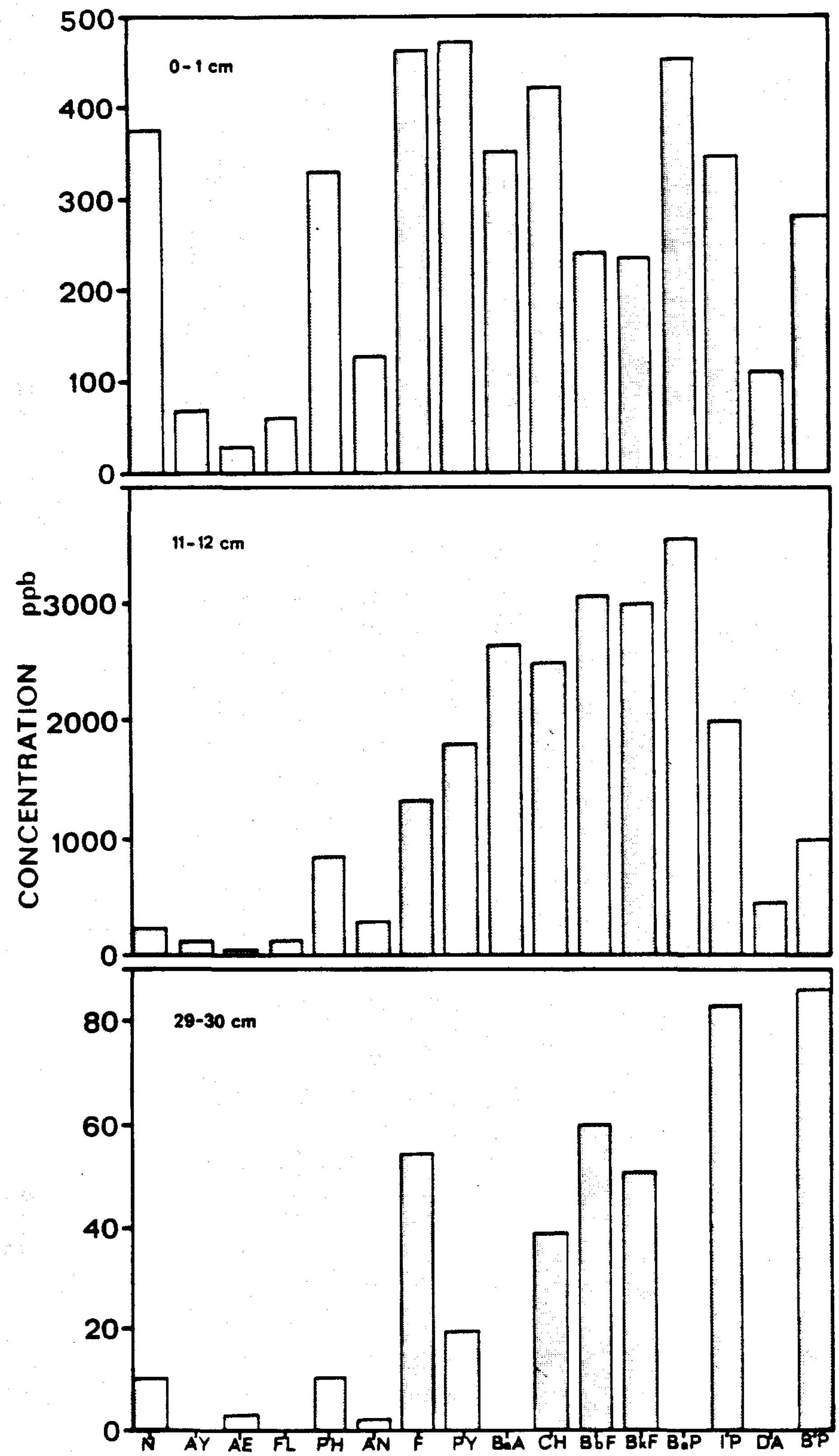

FIGURE VI-18. Vertical distribution of PAHs in Lake George sediments (station 102, 1986).

TABLE VI-10

Results from metal analyses in a sediment core sample collected during 1986 at OMOE station 102 in Lake George (ug/g, dry weight).

Depth cm	Ni	Co	Cr	V	Zn	Cu	Pb
0-1	41	18	95	59	199	35	41
1-2	41	16	107	50	191	34	37
2-3	45	17	95	57	193	35	39
3-4	42	91	91	54	185	35	35
4-5	44	17	99	60	238	35	48
5-6	44	20	98	54	259	34	51
6-7	44	17	100	60	328	35	61
7-8	43	18	102	57	332	35	61
8-9	43	17	99	57	369	41	75
9-10	44	18	104	60	365	38	82
10-11	45	19	111	60	384	39	94
11-12	42	19	121	65	410	39	89
12-13	42	17	123	68	407	37	78
13-14	39	18	141	63	379	33	72
14-15	41	18	184	68	334	34	71
15-16	39	18	189	63	257	29	62
16-17	39	17	152	67	227	33	57
17-18	43	16	117	62	188	33	48
18-19	41	16	94	63	154	34	42
19-20	40	16	89	63	139	37	39

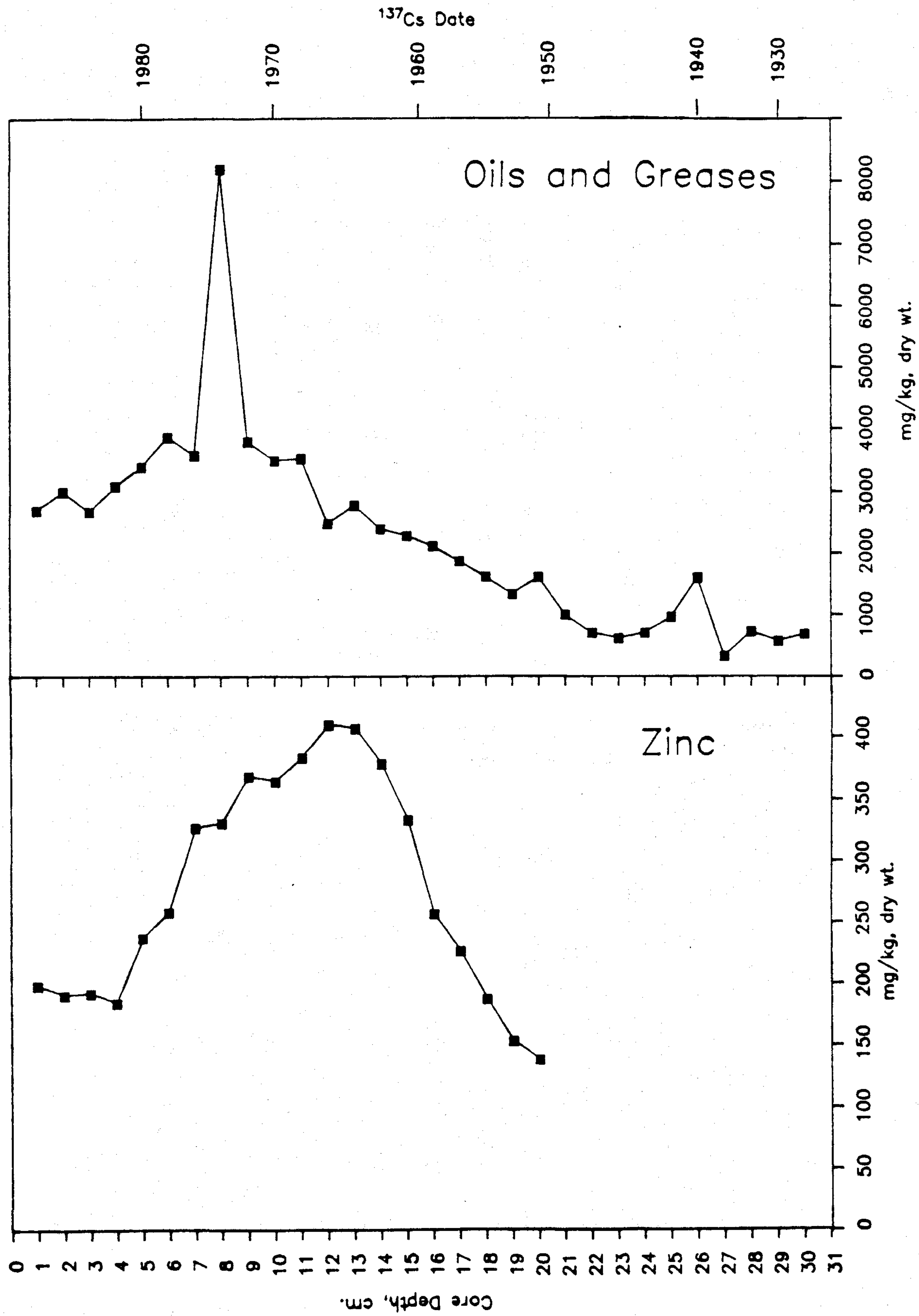

FIGURE VI-19. Oils and greases, and zinc in Lake George sediments (station 102, 1986).

In summary, results from the core sample reflect the effectiveness of the ban on DDT and PCB and the reduction of total PAHs, oil and grease, zinc, chromium and lead loadings to the St. Marys River over the past 20 years.

iv) Spatial Distribution of Contaminants in Surficial (Recent) Sediments

During 1985, the U.S.EPA and FWS collected sediment samples from 125 stations (Figure VI-20) covering the entire St. Marys River (41). The OMOE collected sediment samples at 71 river stations (Figure VI-21) and 8 Canadian tributaries (38).

In comparing the levels of contaminants in sediments, comparison is made to the OMOE Guidelines for Dredge Spoils for Open Water Disposal and the U.S.EPA Guidelines for Pollutional Classification of Great Lakes Harbor Sediments (Table III-4, Chapter III). These guidelines are not based on biological effects and, therefore, will not provide insight into impacts on the river ecosystem. However, their use provides a comparison of relative concentrations. There are no ecologically based sediment guidelines.

Hesselberg & Hamdy (38) found that oil and grease, loss on ignition (total volatile solids), cyanide (CN), arsenic (As), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn) exceeded both U.S.EPA and OMOE guidelines in 20% or more of the samples in at least one group of samples (Table VI-11). Concentrations of chromium, copper, and iron (Fe) most consistently exceeded both U.S.EPA and OMOE guidelines.

The percent of samples exceeding both U.S.EPA and OMOE guidelines in the vicinity of industrial discharges, as well as further downstream, are shown in Table VI-12 (33,34,35,36,37,38,39,40,41, 42). Percents were calculated using the lowest of U.S.EPA moderately polluted or OMOE guidelines for each contaminant. It is apparent from Table VI-12 that the area near Algoma Steel, the City of Sault Ste. Marie, Ontario, and Little Lake George represent the most contaminated areas in the St. Marys River. However, as shown by the spatial distribution of zinc and oil and grease in surficial sediments during 1973 and 1983 (42), both the areal and downstream extent of heavily polluted sediments has decreased (Figures VI-22 & 23). This coincides with the core data from Lake George (Figure VI-19).

Contaminant concentrations in Lake George sediment samples were lower overall. However, over 20% of the samples exceeded the guidelines for most contaminants except for PCBs and cadmium. Lake Nicolet sediment samples exhibited a much lower frequency of contaminants exceeding guidelines but As, Cr, Cu, Fe, Ni and Zn still exceeded guidelines in 14% or more of the samples. In Lake Munuscong and Lime Island Channel a surprising percent of samples

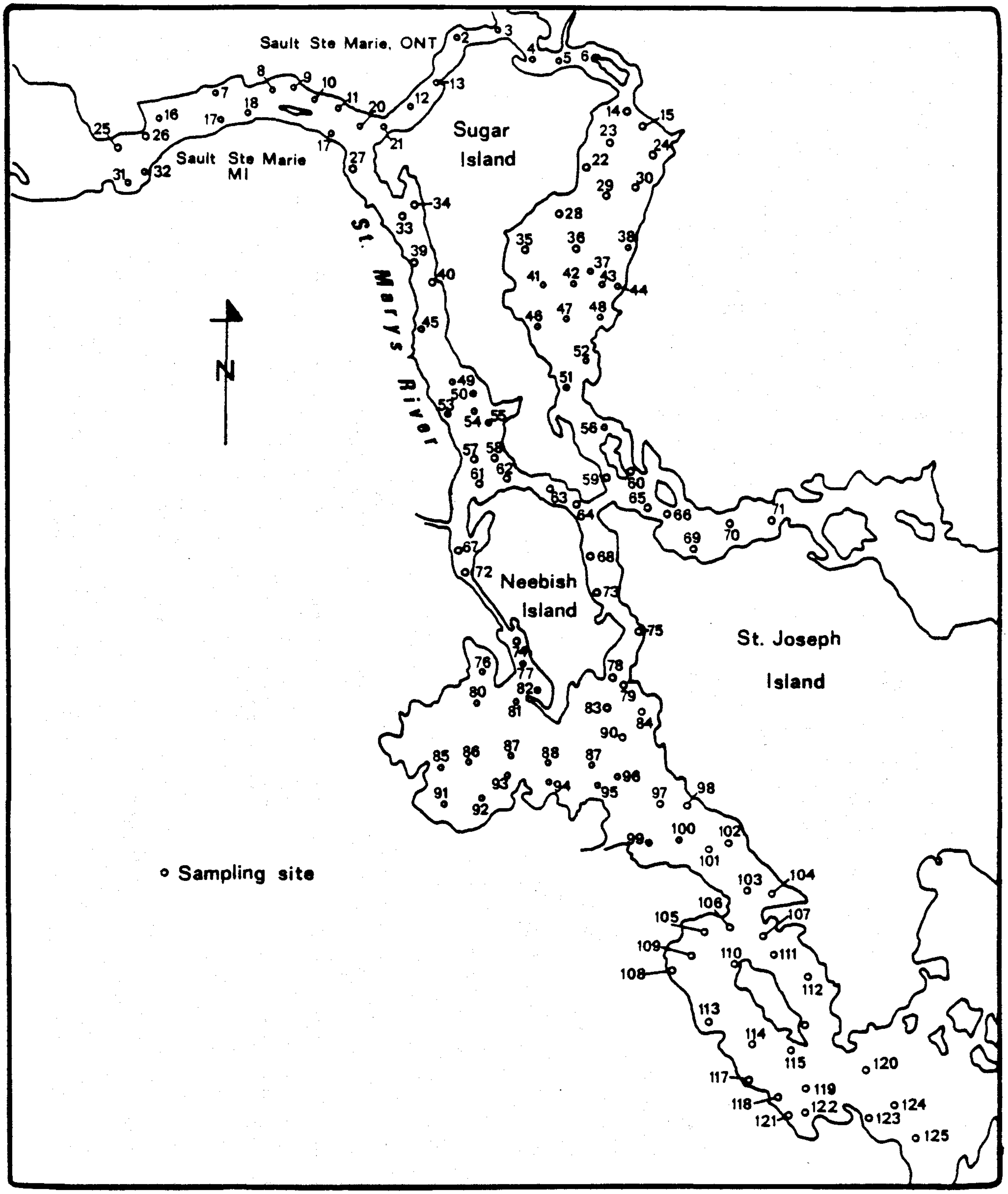

FIGURE VI-20. U.S. EPA/FWS St. Marys River 1985 sediment sampling sites.

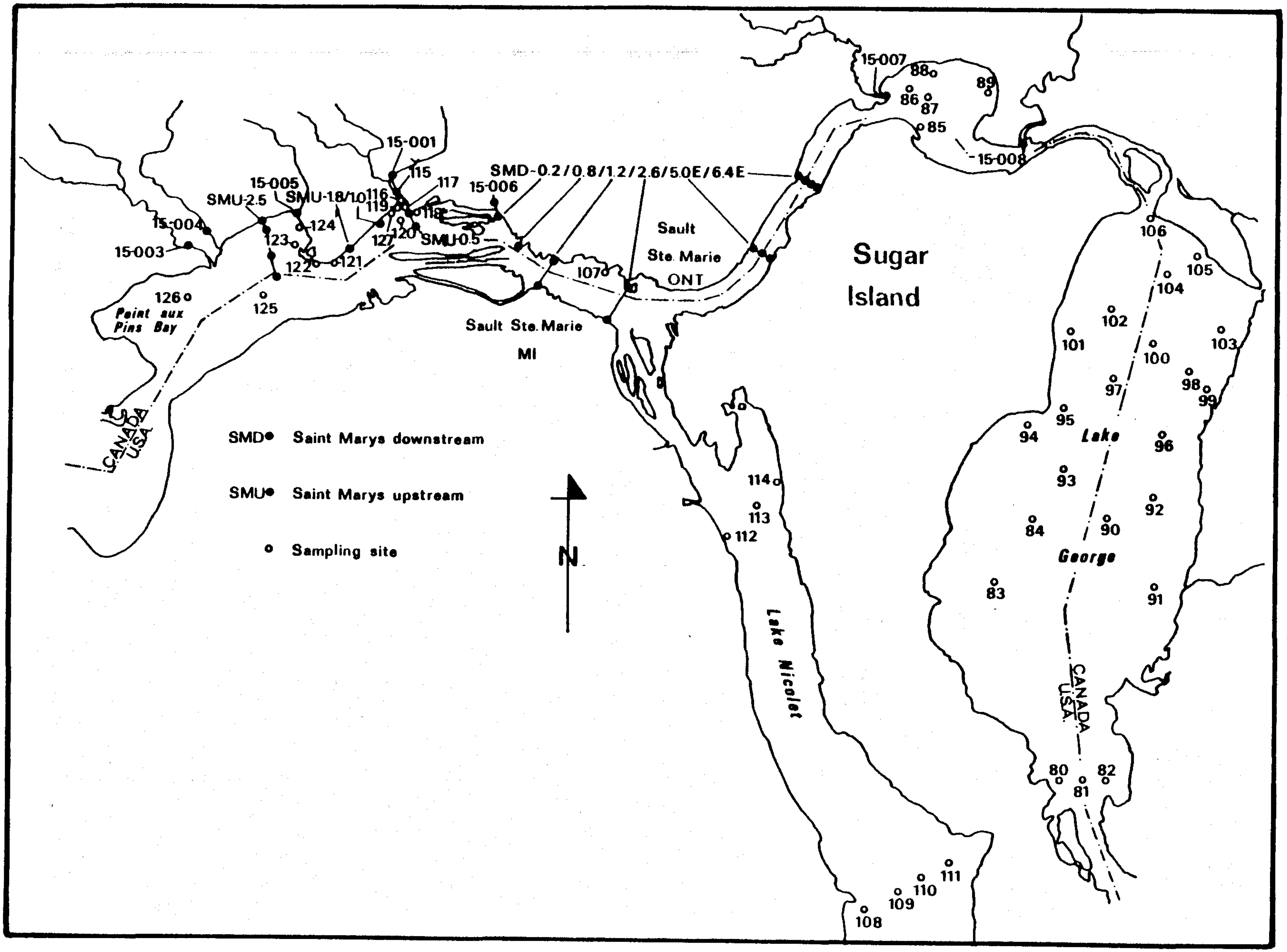

FIGURE VI-21. MOE 1986 St. Marys River sediment sampling sites.

TABLE VI-11

Percent of sediment samples collected from the St. Marys River during 1985 by U.S.EPA, USFWS, or OMOE that exceeded moderately polluted U.S.EPA and/or OMOE sediment pollutation guidelines given in mg/kg, except where noted.

Sources of Samples	Total Samples	Oil and Grease	Percent Loss on Igni-tion	P	TKN	Cyanide	PCBs	As	Cd	Cr	Cu	Fe%	Pb	Hg	Ni	Zn
		% Exceeding U.S.EPA Moderately Polluted Guidelines														
Guidelines		1000	5	420	1000	0.1	1*	3	<6*	25	25	1.7	40	1	20	90
U.S.EPA 1985	19	5	5	63	10	100	0	0	0	44	17	26	0	0	32	0
U.S.EPA/FWS 1985	125	17	18	NA	NA	78	1	NA	0	56	34	NA	11	0	34	18
OMOE 1985	71	42	28	45	35	NA	0	58	0	58	49	44	34	0	21	49
		% Exceeding OMOE Guidelines														
Guidelines		1500	6	1000	2000	0.1	0.05	8	1	25	25	1	50	0.3	25	100
U.S.EPA 1985	19	0	5	0	0	100	0	0	0	44	17	47	0	0	32	0
U.S.EPA/FWS 1985	125	10	12	NA	NA	78	27	NA	4	56	34	NA	9	1	19	17
OMOE 1985	71	38	21	0	NA	NA	14	31	3	58	49	66	23	1	6	46

NA - Not analyzed or not available

* - Heavily polluted

TABLE VI-12

Percent of samples by area at or exceeding U.S.EPA moderately polluted or OMOE sediment pollution Guidelines.

Area Location	Agency Samples	No. Samples	Oil and Grease	Loss on Ignition	Total PCBs	As	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Algoma Steel	U.S.EPA/FWS	8	25	38	12	NA	0	50	38	NA	38	12	38
Sault Ste. Marie	OMOE	9	56	55	11	89	0	78	67	89	44	22	56
Little Lake George	U.S.EPA/FWS	4	50	50	50	NA	50	50	50	NA	50	50	50
	OMOE	5	100	60	20	100	20	0	100	100	60	4	100
Lake George	U.S.EPA/FWS	24	21	12	17	NA	0	33	29	NA	21	25	29
	OMOE	22	45	32	0	72	5	64	59	95	32	36	59
Lake Nicolet	U.S.EPA/FWS	15	0	7	33	NA	7	33	NA	NA	7	7	7
	OMOE	7	14	0	0	29	0	29	14	29	0	14	14
Lake Munuscong	U.S.EPA/FWS	30	0	0	30	NA	0	77	37	NA	0	43	0
	OMOE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lime Island Channel	U.S.EPA/FWS	21	19	5	0	NA	0	76	52	NA	0	62	19
	OMOE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = Data not available or not analyzed

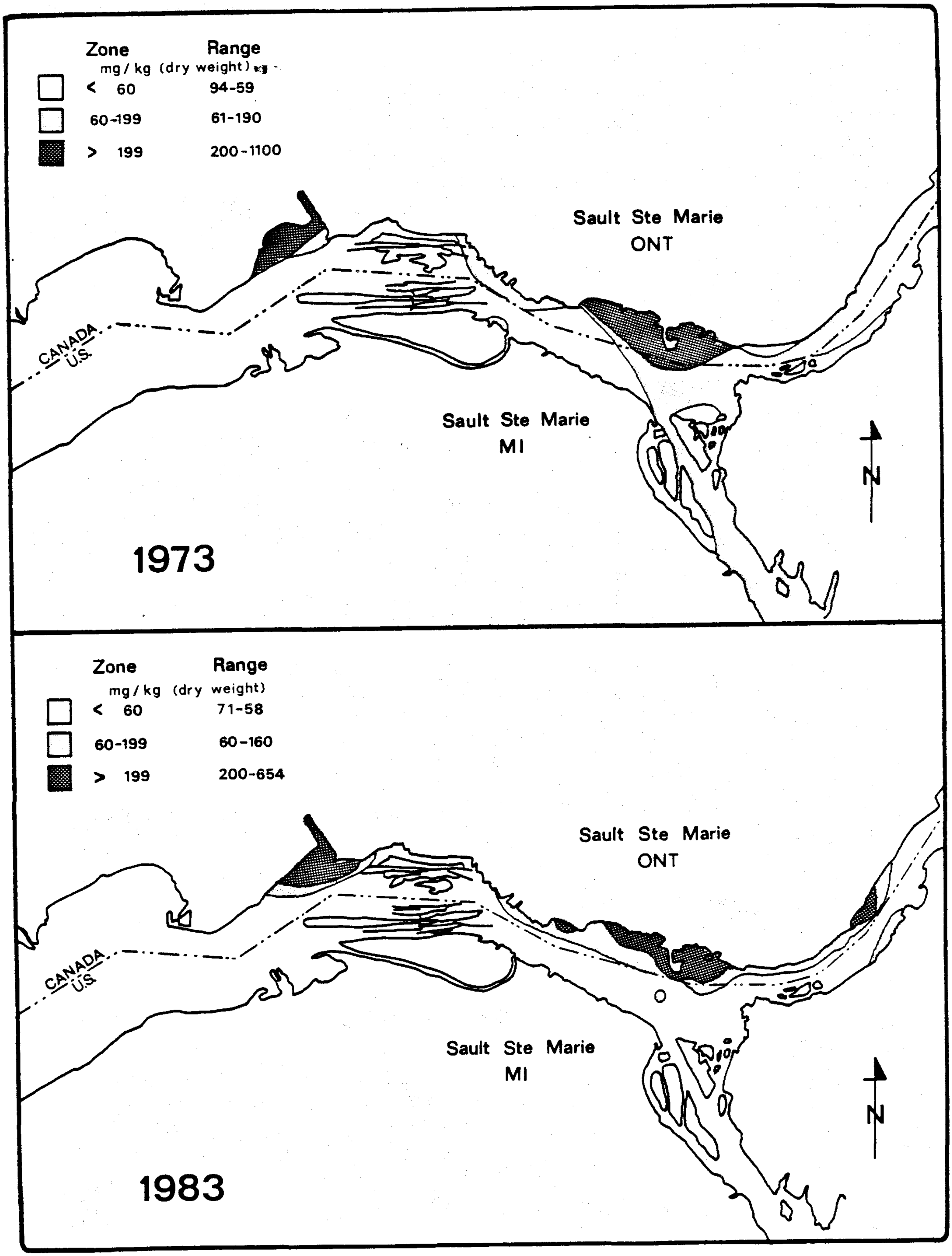

FIGURE VI-22. Distribution of zinc in the St. Marys River surficial sediments.

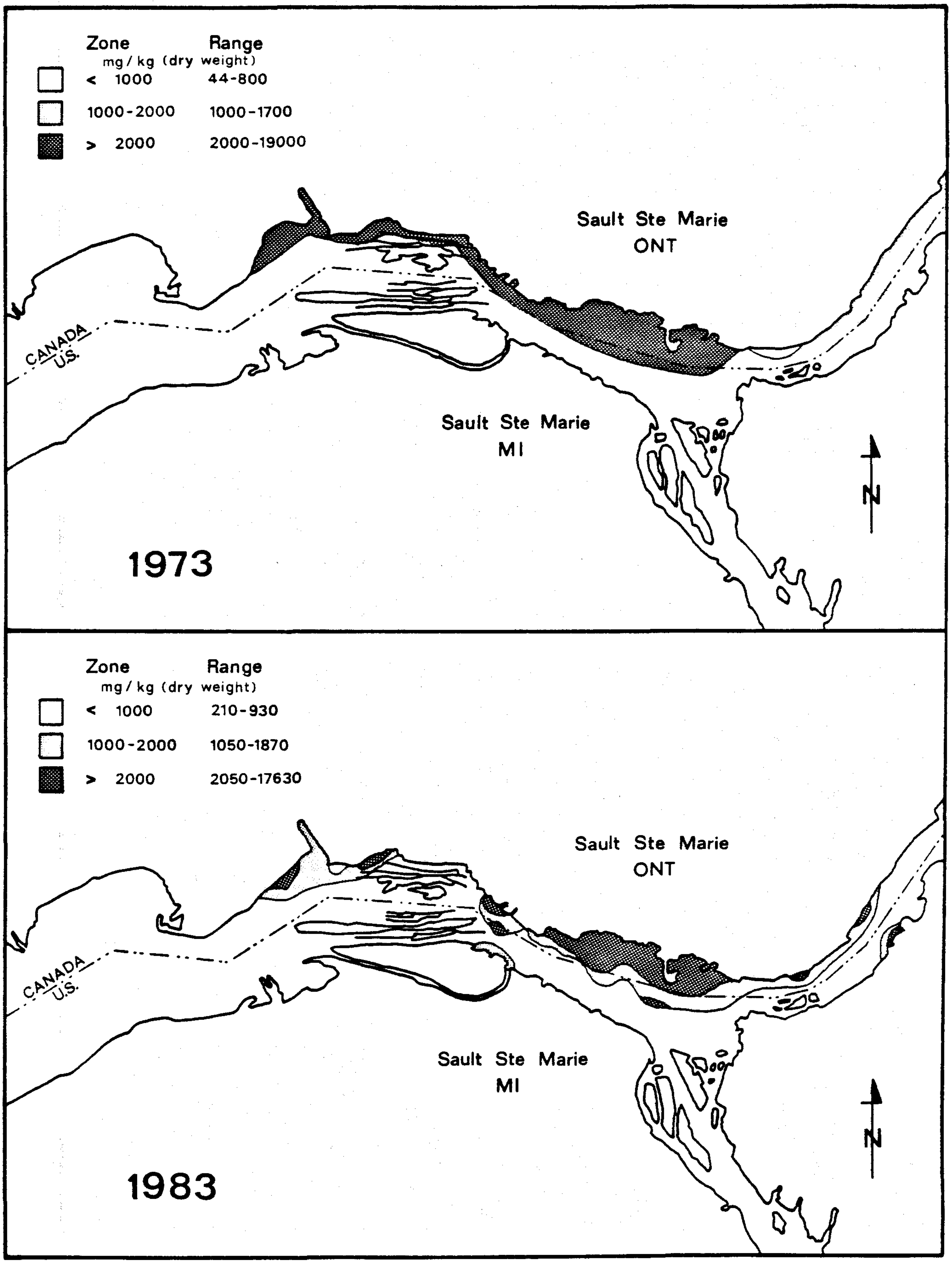

FIGURE VI-23. Distribution of oil and greases in the St. Marys River surficial sediments.

exceeded guidelines for Cr, Cu, and Ni. It appears these elements settled out with the sediment in the slower moving waters.

Most chlorinated organic contaminants had low concentrations in the sediment. PCBs exceeded OMOE guidelines in the upper river; however, no more than 1% of the total samples exceeded the U.S. EPA moderately polluted guideline.

The distribution of PAH compounds (Figure VI-24) indicated that sediment from the Algoma Slip contained the highest levels of total PAHs (711 ug/g). Individual compounds, notably acenaphthene, phenanthrene, anthracene, fluoranthene, pyrene, dibenzothiophene and carbazole in the Algoma Slip area were also the highest levels in the river as shown in Table VI-13. A semi-quantitative analysis of samples collected during a coal tar spill investigation in Bennett Creek during 1987 indicated that total PAH concentrations (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benzo(a)anthracene, benzo(b,k)fluoranthene, (benzo(j)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, perylene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)-perylene) were approximately 3,300 ug/g. Bennett creek flows into the Algoma Slip. The Algoma Steel and/or Domtar Inc. operations are likely the major source of PAHs to the slip and Bennett Creek and subsequently to the St. Marys River.

As a result of the strong association of PAHs with silt and clay, higher concentrations of PAHs were found in the embayments downstream from the Terminal Basins than those observed in non-embayments immediately downstream from the discharge.

Along the Michigan shore, with the exception of a location immediately downstream from the Edison Sault Electric Company Canal, total PAHs were similar to background levels (Figure VI-24). Total PAH concentrations immediately downstream of the Edison Sault Electric Company Canal (334 ug/g) may be the result of historical inputs from a coal stockpiling operation on the shore.

Few guidelines are available for PAHs in sediments. However, the IJC has (1983) (33) proposed an objective of 1 ug/g for benzo(a)-pyrene. This concentration was exceeded along the Ontario shoreline in samples from the east end of the Algoma Slag Site to as far downstream as the beginning of the Lake George Channel and also below the Edison Sault Canal in Michigan.

Tributaries may also contribute contaminants to the river system. In the vicinity of Algoma Steel and the City of Sault Ste. Marie Ontario, tributaries such as East Davignon and Fort Creeks are likely sources of As, Cr, Cu, Fe and oil and grease. Fort Creek is also likely a source of Ni, Pb, Zn and total PCBs. The levels of Cr, Ni and Fe in McFarland Creek, a tributary to Little Lake

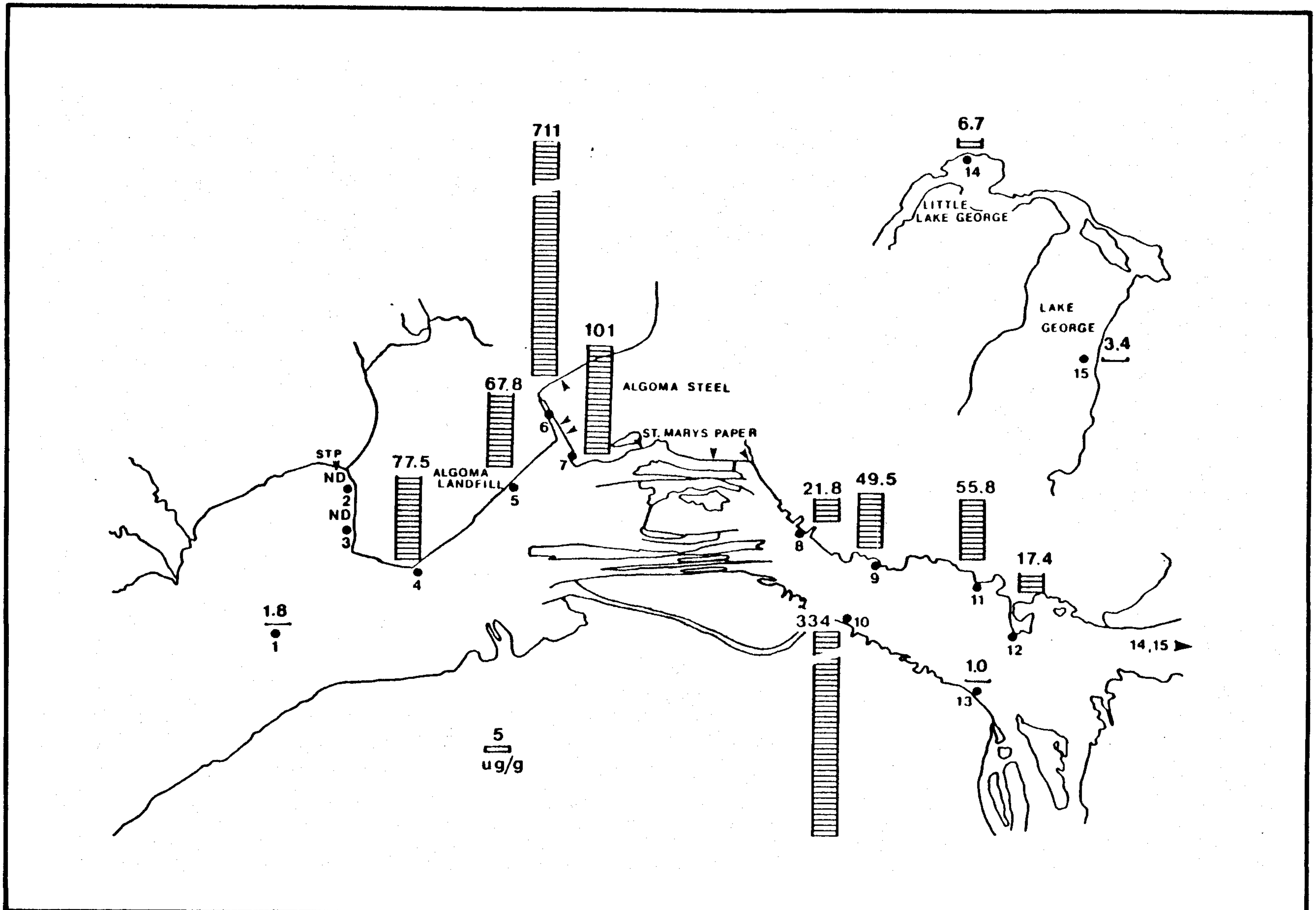

FIGURE VI-24. Total PAHs in surficial sediments in the St. Marys River (1985).

TABLE VI-13

PAHs in sediments in the St. Marys River, 1985 (ug/g).

COMPOUNDS	STATION 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Naphthalene	ND	ND	ND	0.06	3.4	29	33	0.06	5.9	0.69	6.6	1.7	0.03	0.13	0.125
Acenaphthylene	0.2	ND	ND	0.08	0.93	4.8	0.42	0.42	0.55	4.6	0.52	0.55	ND	0.18	0.07
Acenaphthene	ND	ND	ND	ND	1.1	19.5	0.93	ND	0.18	0.62	0.17	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	2.3	28.5	1.9	0.06	0.47	3.4	0.36	0.17	ND	ND	0.03
Phenanthrene	0.07	ND	ND	0.86	13	185	14	0.29	3.9	25	2.2	1.1	0.09	0.4	0.25
Anthracene	0.1	ND	ND	ND	4.5	37	3.5	0.22	1.4	10	1.0	0.52	0.03	0.18	0.07
Fluoranthene	0.14	ND	ND	4	11	135	13	0.53	6.4	30	3.7	1.7	0.12	0.59	0.425
Pyrene	0.09	ND	ND	3	5.6	71.5	7.4	0.32	3.6	17	2.2	1.1	0.07	0.36	0.27
Chrysene	ND	ND	ND	3.4	1.1	9.3	1.5	0.26	1	9.9	1.0	0.45	0.02	0.14	0.06
Benzo(a)anthracene	0.21	ND	ND	18	4.2	32	5.5	1.3	4.6	36	4.2	2.1	0.09	0.55	0.28
Benzo(b,k)fluoranthene	0.44	ND	ND	16	4.8	32.5	4.3	5.5	6.2	67	11.0	2.8	0.13	0.97	0.325
Benzo(j)fluoranthene	ND	ND	ND	1.1	0.9	5.5	0.64	1.8	1.1	17	3.0	ND	ND	0.16	0.06
Benzo(e)pyrene	0.24	ND	ND	7.4	2.6	16.0	2.1	4.3	3	37	7.0	2	0.08	0.56	0.18
Benzo(a)pyrene	0.35	ND	ND	9.2	3.5	24.5	2.8	4.3	4.4	48	8.4	1.9	0.11	0.71	0.21
Perylene	ND	ND	ND	2.2	1	7.3	0.74	1.4	1.2	11	2.3	0.55	0.032	0.33	0.11
Indenol(1,2,3-c,d)pyrene	ND	ND	ND	3.6	1.2	5.3	0.82	0.7	1.1	4.9	0.69	ND	0.04	0.34	0.07
Dibenzo(a,h)anthracene	ND	ND	ND	1.5	0.55	2.3	0.35	ND	0.46	2.5	ND	ND	ND	0.11	0.025
Benzo(g,h,i)perylene	ND	ND	ND	3.5	1.1	4.5	0.82	0.2	0.88	1.7	0.21	ND	0.04	0.31	0.065
Benzothiophene	ND	ND	ND	ND	0.45	3.8	0.39	ND	0.31	0.06	0.26	ND	ND	ND	0.06
Quinoline	ND	ND	ND	ND	0.07	0.46	0.12	ND	ND	ND	ND	ND	ND	ND	0.03
Dibenzothiophene	ND	ND	ND	ND	1.8	24.5	1.7	ND	0.59	2.3	ND	0.14	ND	ND	0.15
Acridine	ND	ND	ND	0.58	0.71	8.7	1.3	0.08	0.61	1.2	0.22	0.16	0.08	0.25	0.195
Carbazole	ND	ND	ND	0.28	0.8	14	1.7	ND	0.81	2.2	0.3	0.1	0.04	0.26	0.186
Benz(a)acridine	ND	ND	ND	2.7	1.2	10.2	1.5	0.13	0.84	5.7	0.49	0.31	ND	0.13	0.186
Dimethyl benz(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Coronene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PAHs	1.84	ND	ND	77.5	67.8	711	100.5	21.8	49.5	334	55.82	17.4	1.0	6.66	3.42

George, represented a moderately polluted sediment according to the U.S.EPA Dredging Guideline. The levels were 38 mg/kg, 25 mg/kg and 19,000 mg/kg, respectively.

In 1985, U.S.EPA collected 19 samples of bottom sediment from 18 Michigan tributaries. The samples were analyzed for a broad range of conventional pollutants, metals, pesticides, PCBs and other organic chemicals (43). Various benthic organisms were present in most samples and there was no obvious evidence of pollution. Analyses for conventional pollutants, metals, aromatics, DDT and metabolites, phthalate esters, PCBs, and PAHs indicated that, although some parameters resulted in the sediment being classified as moderately polluted (U.S.EPA guidelines), most were classified as nonpolluted. The results of this study indicate that Michigan tributaries are not a significant source of contaminants to the St. Marys River. Samples collected from streams which drain the City of Sault Ste. Marie, where contaminant sources are most likely, were generally free of significant contaminant concentrations. Exceedances of specific U.S.EPA guidelines are believed to be the result of natural sources.

B. SPECIFIC CONCERNS

Table VI-14 summarizes contaminants of concern in the St. Marys River by matrix. The following discussion provides more detailed information on the areas or species impacted. In general, where the same contaminant was measured in all matrices (e.g., PAHs) the zones of environmental impact were similar.

1. Water

Degradation of the water quality in the St. Marys River resulting from industrial and municipal discharges is a concern for citizens of Sault Ste. Marie, Ontario and Michigan. Generally the concerns are focussed on the possible combined toxic effect of ammonia, cyanide and heavy metals (e.g. zinc); excessive amounts of oil and grease as a result of discharges or spills; phenols which continue to exceed the objective, albeit in a small zone downstream from the industrial discharges; and PAHs because of the carcinogenic nature of certain PAH compounds.

Water quality impairment in the St. Marys River is mainly restricted to a narrow band along the Canadian shore, downstream of Algoma Steel and St. Marys Paper effluent discharges. Partial recovery from the effects of these industrial inputs takes place throughout the St. Marys River downstream, however, discharges from the Sault Ste. Marie, Ontario East End WWTP delay the complete restoration of satisfactory water quality with respect to several contaminants (i.e. phenols, ammonia, cyanide) until Lake George. There is some transboundary pollution in the Lake George Channel.

A band of phenols which slightly exceeds the PWQO and the GLWQA specific objective of 1 ug/L was noted along the Canadian shore for a distance of 3 km below the Terminal Basins discharge. Although ammonia and cyanide levels are within their respective objectives throughout the St. Marys River, the combined effect of these contaminants may result in toxic conditions.

In the St. Marys River, measured PAHs associated with the aqueous phase of the water column increased downstream from Leigh Bay, reaching a peak concentration in the Algoma Slip. Although PAHs are commonly reported as a group, the toxicity and relative carcinogenicity of individual substances vary greatly as shown in Table VI-15. In the aqueous phase, 95% of the PAH compounds measured in the St. Marys River were considered to be not or weakly carcinogenic. Estimated concentrations of PAHs associated with the whole water phase exceeded the U.S.EPA AWQC for Human Health Criteria (for fish consumption) of 31 ng/L for total PAHs from the Algoma Slag Site to downstream of the Sault Ste. Marie, Ontario East End WWTP. Estimates of PAHs associated with both the whole water and aqueous phase that are considered noncar-

TABLE VI-14

Summary of contaminants of concern in the St. Marys River.

CONTAMINANT	MATRIX					
			BIOTA			
	WATER	SEDIMENT	BENTHOS COMM.	OLIGO- CHAETES	CAGED CLAMS	SPORT FISH
Bacteria (Fecal coliform)	E					
Phosphorus	E		I			
Ammonia	P		I			
Cyanide	P					
Heavy Metals						
- Chromium		E	I			
- Copper		E		P		
- Lead		E				
- Mercury		E		P		E
- Nickel		E				
- Zinc	P	E		P		
- Iron	E	E				
Phenols	E		I			
Oil and Grease	P	E	I			
PCBs, total		P				P
PAHs, -total	P				P	
- Benzo(a) pyrene	E	E	I(?)		P	

Notes:

E = exceeds available guideline
P = present above background
I = impacted by contaminant indicated

TABLE VI-15

Carcinogenic activity of individual PAHs.

Individual PAHs	Carcinogeric	Potential
	*	**
Naphthalene		
Acenaphthylene	-	Inactive
Acenaphthene		
Fluorene	-	
Phenanthrene	-	Inactive
Anthracene	-	Inactive
Fluoranthene	-	
Pyrene	-	Inactive
Benzo(a)anthracene	-	Disputed
Chrysene	+/-	Disputed
Benzo(b)fluoranthene(2,3-benzfluoranthane)	++	
Benzo(k)fluoranthene(8,9-benzfluoranthane)	-	
Benzo(a)pyrene(1,2-benzpyrene)(3,4-benzpyrene)	+++	High Active
Dibenzo(a,h)anthracene(1,2,5,6-dibenzanthracene)	+++	Moderate
Benzo(g,h,i)perylene	-	Moderate
Indeno(1,2,3-c,d)pyrene(o-phenylene pyrene)	+	
Benzo(e)pyrene(4,5-benzpyrene)(1,2-benzpyrene)	-	Inactive
Perylene		
Benzo(j)fluoranthene(7,8-benzfluoranthene)	++	
Coronene	-	
Acridine	-	
Dibenzo(a,h)acridine(1,2,5,6-dibenzacridine)	++	Slight
Carbazole	-	Slight
Benzo(a)carbazole	-/+	High
Quinoline	+	
Benzo(f)quinoline	-	
Dibenzthiophene		
Benzo(2,3)phenanthro(4,5-b,c,d)thiophene		

* Source: National Academy of Sciences (1972): Particulate Polycyclic Organic Matter; Washington, D.C.
Indications are "-" for not carcinogenic, "+/-" for uncertain or weakly carcinogenic, "+" for carcinogenic and "++, +++" for strongly carcinogenic from (44).

** Source: Polynuclear Aromatic Carcinogens, Dipple, Anthony in Chemical Carcinogens, p., 245-307.

cinogenic constitute greater than 80% of total PAHs at all sites monitored along the St. Marys River. PAH levels along the U.S. shoreline were similar to the background or upstream levels indicating no transboundary pollution.

2. Sediments

Bottom sediments of the St. Marys River exhibited contaminant concentrations that exceeded both the OMOE and U.S.EPA dredged material disposal guidelines. The parameters of concern are arsenic, cadmium, chromium, cyanide, copper, iron, lead, mercury, nickel, zinc, nutrients, and oil and grease. Most of these contaminants, together with chlorinated organics and PAHs, are of concern due to bioconcentration and the potential for toxic effects.

Sediments along the Ontario shore near Algoma Steel and Sault Ste. Marie and in Little Lake George were the most contaminated in terms of percent of samples having concentrations equal to or greater than dredged material disposal guidelines. The sediments in the St. Marys River upstream of the industrial complexes were uncontaminated.

Sediments containing chlorinated organic contaminants, coupled with external loadings, may result in excessive body burdens for aquatic life. Sediment core data indicates improvements but PAH concentrations remain a concern. As a result of the strong association of PAHs with silt and clay, higher concentrations were found in the embayments downstream from the Terminal Basins.

3. Biota

Benthic macroinvertebrate distribution in a system is often used as an indicator of ecological health and environmental impact. Normal benthic communities are characterized by diverse populations, presence of pollution intolerant taxa (e.g. caddisflies), and a relatively higher number of organisms per unit area. Adversely impacted benthic communities in the St. Marys River generally were restricted to a narrow band approximately 500 m wide, extending 3 km along the Canadian shore downstream of industrial discharges. Some recovery was apparent with increasing distance (e.g., 5 km) downstream from the Algoma Steel and St. Marys Paper discharges, however, complete recovery was not realized until the lower section of Lake George, some 24 km downstream from these discharges. Recovery was, in part, delayed by effluent from the East End WWTP. Clean water fauna characterized the nonindustrialized U.S. shore, the whole river upstream of pollution sources, and Lake Nicolet.

Despite reductions in certain pollutants from Algoma Steel, St.

Marys Paper, and the East End WWTP little improvement has been observed in the benthic community of the St. Marys River. Contaminants in the sediments, together with contaminants in the water column, are thought to severely restrict the survival of most macroinvertebrates in certain areas of the St. Marys River. It was generally observed that areas with visible oily residues were characterized by the absence of ephemeropteran Hexagenia.

Elimination or alteration of normal populations of aquatic insects and other invertebrates and their replacement by pollution tolerant species (which have limited value as fish food organisms) will also result in the alteration of the suitability of the river for supporting game fish populations. Further, contaminated sediments are a likely source of contaminants to benthic organisms and can exert toxic influences on them, either completely eliminating benthic populations or reducing the diversity to a few tolerant species. Uncontaminated clams exposed to river water near and downstream of the discharges accumulated significantly higher levels of certain PAH compounds, than clams introduced in the river upstream from the discharges.

The effects of contaminants on the food web in the St. Marys River and ecosystem is a concern that should be fully investigated. Toxic compounds that are deposited in the sediments may transfer to water, biota, and the atmosphere. Sediments may not be the final sink for persistent contaminants (e.g. PCBs) but may rather act as a source through redistribution of compounds to water and the atmosphere (45).

In general, it appears that past reductions in pollutant loadings to the St. Marys River have not been adequate to reduce sediment contamination and impacts to benthic organisms. The contaminants remaining in the sediment, particularly oil and grease but also metals and PAHs, are a major concern in this channel.

4. Uses Impaired

Fish Consumption

Fish from the St. Marys River (collected below the rapids) do not currently contain levels of organochlorines (PCBs; DDT; lindane; 2,3,7,8-TCDD) above available consumption guidelines. The consumption advice tables in the 1988 "Guide to Eating Ontario Sport Fish" indicate that mercury levels in large specimens of some game species (i.e. lake trout, northern pike, and walleye) are between 0.5 and 1.0 ppm and thus long-term consumption should be restricted to 0.226 kg/wk. It is recommended that children under 15 years of age and women of child bearing age should consume only those fish with a mercury content of less than 0.5 ppm. Mercury concentrations in fish are believed to be the result of natural sources.

Young-of-the-year yellow perch collected from Sault Ste. Marie, Ontario contained PCBs, but these concentrations (average 25 ppb) were well below the GLWQA Objective (100 ppb) for the protection of birds and animals which consume fish. No detectable levels of chlorophenols or chlorinated aromatics were found in these fish.

Preliminary analysis of whole fish showed that two bottom feeding species from the North Channel of Lake Huron contained detectable levels (low ppb range) of some PAHs. The only guideline for PAHs is the U.S.EPA AWQC Human Health Criteria of 31 ppb (ng/L) based on consumption of 6.5 gm of fish per day.

Aesthetics

In recent years, the occurrence of aesthetic problems has become less frequent than previously observed. Mats of oily fibrous material mixed with fine wood chips are noticed only occasionally on the Sault Ste. Marie waterfront extending as far as the Lake George Channel. These intermittent problems are, in part, due to the decomposition of fibers and fine wood particles found to be prevalent in the river sediments along the Canadian shore.

Occasional oil slicks resulting from spills have been sighted on the St. Marys River. However, the oil slicks have lately been confined to the Algoma Slip area and very occasionally downstream of the Terminal Basins. This suggests that the oil booms in the slip area are effective in containing the spills but that the oil separators at the Terminal Basins are not 100% effective.

Habitat

Commercial navigation, both the vessel traffic and engineering modifications of the river (i.e. building of locks, canals, and dredging), affect the aquatic biota and their habitats in the St. Marys River. Important fish spawning and rearing habitats have been destroyed by modification for locks and channels. Regulated flows for hydro power development have occasionally resulted in dewatering of the St. Marys Rapids with the resultant loss of benthic macroinvertebrate and fish productivity.

The shipping channel is essentially a portion of the soft bottom habitat which has been altered by dredging. The shipping channel is poor habitat for benthic macroinvertebrates as only two taxa are common, and both diversity and density are much lower in the shipping channel than in all other habitats. Turbulence created by passing ships and their propeller wash and oil spills are likely the reason for the lack of benthic organisms in the shipping channel. There are, however, no indications of pronounced sediment bound toxicity in the St. Marys River as a result of navigational activities (46).

The aquatic organisms in the emergent wetlands may be affected by ship passage which results in the temporary drawdown along the shore. A study of emergent wetland invertebrate populations of the St. Marys river showed that 18.9% of the mortality of Lestes disjunctus was attributable to ship passage (47). Drawdown induced by ship passage may also affect the survival of larval fish that inhabit the wetlands (48). Sediment is transported and deposited at increased rates during ship passage, and survival of aquatic organisms is threatened.

The present and proposed expansion of the dredging operation by A.B. McLean Ltd. at the headwaters of the St. Marys River (Whitefish Bay) is a concern to both Ontario and Michigan citizens. This proposed operation may allow up to 500,000 m^3 per year of sand and gravel to be dredged. Because Whitefish Bay is a major spawning habitat for Lake Superior whitefish, the Ontario government has requested A.B. McLean Ltd. to submit a detailed fisheries assessment of the current and proposed operation.

A.B. McLean Ltd. has also altered the southwest shoreline of the Algoma Slag Site to develop a dock facility. Development of the dock included the sinking of an old ore carrier and the dredging of the river bottom. Concern was expressed about the resulting downstream siltation.

C. SOURCES

Pollutants enter the St. Marys River system from both point and nonpoint sources. Point sources include effluents from municipal and industrial wastewater treatment facilities directly to the river and indirectly via tributaries. Nonpoint sources include atmospheric deposition, intermittent stormwater discharges, combined sewer overflows, rural land runoff, navigation, groundwater migration (including pollutants coming from waste disposal sites and landfills) and release from bottom sediments.

1. Point Source

An inventory of direct and indirect point source discharges to the St. Marys River is presented in Table VI-16. Direct point sources are defined as those facilities discharging directly into the St. Marys River, while indirect sources are those discharging to a tributary of the St. Marys River. There are no indirect municipal sources. The only major indirect industrial sources are the Algoma Steel Tube Mill and Cold Mill (cooling water only) which discharge to East Davignon Creek. The total 1986 annual average flow of municipal wastewater was 59 X 10^3 m^3/d. Industrial flows were 530 x 10^3 m^3/d.

All Ontario direct point source discharges were sampled by Environment Canada and OMOE in a 3 to 6 day survey conducted in August 1986 (49). Average daily gross loadings calculated from the survey results are presented in Table VI-17.

Loading estimates from the August 1986 UGLCCS survey were compared to estimates based on two long-term surveys; the OMOE MISA pilot site study (May to November 1986) and the effluent self-monitoring program (January to December 1986). This comparison revealed that loadings for phenols, total PAHs, ammonia, suspended solids and oil and grease from Algoma Steel are quite variable and that the UGLCCS data for some parameters are probably not representative of the operational conditions of treatment facilities. Therefore, average gross loadings calculated from the self monitoring or MISA pilot site data are introduced and included in Table VI-17. Table VI-18 illustrates the marked variability in concentrations of contaminants in effluents over a 1 year period (MISA data).

The total loading of oil and grease to the St. Marys River during the UGLCCS survey was approximately 10,000 kg/d. An average of 9,488 kg/d was discharged from Algoma's Terminal Basins, far exceeding the Control Order limit of 1,589 kg/d which was to be met by December 31, 1986. The oil and grease loading from Algoma during the UGLCCS survey was well above the average daily load as calculated from 1986 (annual) self monitoring data (1,950 kg/d), the August 1986 self-monitoring data (1,470 kg/d) and the MISA

TABLE VI-16

St. Marys River point source inventory.

Name and Location	Type of Facility	Population Served/ Production	Receiving Stream	Outfall Name(s)	1986 Average Annual Flow 103m3
Direct Dischargers					
Municipal					
1. Sault Ste. Marie, Ontario, East End WPCP	Primary (without phosphorus removal)	52,000	St. Marys River	Final effluent	41.7
2. Sault Ste. Marie, Ontario West End WPCP	Secondary, with continuous phosphorus removal	17,500	St. Marys River	Final effluent	9.1 (1986-first year Operation)
3. Sault Ste. Marie, Michigan, POTW	Secondary, with chlorination with phosphorus removal	15,000	St. Marys River	Final effluent	8.0
Industrial					
4. St. Marys Paper, Sault Ste. Marie, Ontario	Groundwood Pulp and Paper Mill	106,000 T/yr	St. Marys River	Final effluent	27.5
5. The Algoma Steel Corp., Ltd., Sault Ste. Marie Ontario	Integrated Steel Mill	3.5 x 106 T/yr	St. Marys River	Terminal Basin	354
				Bar and Strip Lagoon	59.5
				60" Blast Funace Sewer	45.9
				30" Blast Funace Sewer	29.5
			TOTAL FLOW		575.2
Indirect Discharges					
Municipal					
None					
Industrial					
6. The Algoma Steel Corp. Ltd., Sault Ste. Marie Ontario	Integrated Steel Mill		East Davignon Creek	Tube Mill Outfall	6.2
				24" Cold Mill Basin OTCW	7.8

TABLE VI-17

Loading summary of point source discharges to the St. Marys River (kg/d)[1].

Parameter	Algoma Steel	St. Marys Paper	East End WWTP	West End WWTP	Michigan WWTP	E. Davignon Creek	Fort Creek	Bennett Creek	Total Loadings to St. Marys R.
Flow (m3/d)	486,375	23,710	30,638	8,753	7,972	87,048	3,145	3,145	650,786
Oil and Grease	9,441	231	349.7	13.3	NA	NA	NA	NA	10,035
	(1950)+								
	(3547)**								(4141)
Ammonia	6,254	6.01	195.5	14.8	NA	17.6	0.172	2.8	6,481
	(3990)*								(4227)
Total Phosphorus	20.0	4.70	89.8	5.7	6.3@	2.7	0.41	0.066	129.6
Suspended Solids	4,234*	2,829	900.6	39.4	47.3@	1,713	353	158	10,274
	(8137)*								(15300)
Chloride	18,885	743	2011.1	598.5	NA	952.6	286	671	24,137
Cyanide	72.9	NA	NA	NA	NA	0.294	0.0031	0.022	73.2
Total Phenols	9.0	0.708	0.512	0.022	NA	0.61	0.0041	0.075	11
	(96.5)*								
	(114)**								(116)
Copper	-1.1	0.328	1.4	0.2	NA	NA	NA	NA	0.83
Iron	1,747	8.65	42.6	5.2	NA	71.8	12.2	1.22	1,889
	(2275)**								(2417)
Lead	4.81	0.168	1.01	0.187	NA	NA	NA	NA	6.18
Mercury	0.005	0	0.0005	0.0001	NA	NA	NA	NA	0.0056
Zinc	33.7	0.09	1.91	0.356	NA	0.761	0.127	0.054	37.3
Xylene	0.388	0.05	0.223	ND	NA	ND	ND	NA	0.66
Styrene	0.084	ND	NA	ND	NA	NA	NA	NA	0.084
Benzene	1.12	0	0.048	0.011	NA	ND	ND	NA	1.18
Chloroform	0.004	0.066	0.079	0.031	NA	ND	ND	NA	0.18
Methylene Chloride	0.124	0.0088	0.233	0.030	NA	NA	NA	NA	0.4
Toluene	0.231	0.168	0.158	0.005	NA	ND	ND	NA	0.56
2,4,6-Trichlorophenol	1.48	0	0.004	0.037	NA	NA	NA	NA	1.52
2,4-Dimethylphenol	1.21	-0.06	0.727	0.075	NA	NA	NA	NA	1.95
Total PAH's (16)	0.20	0.051	0.417	0.004	NA	0.04	0.006	.005	0.72
	(1.21)**								(1.73)
1,4-Dichlorobenzene	0.125	0.030	0.043	0.010	NA	ND	ND	NA	0.21
Mono & Dichloramine	NA	NA	2.64	0.600	NA	NA	NA	NA	3.24

NA = Not Analyzed, ND = Not Detected

1 (based on data collected in 1986).

\+ 1986 self monitoring data.

* Loadings for Terminal Basins from average for the self monitoring program for 1986 substituted into database as August loadings for those parameters considered atypical.

** Represents data of MOE Pilot Site investigation.

@ Loadings from November 1986 to October 1986 facility monthly operating report.

TABLE VI-18

Mean and range of contaminant concentrations observed in Algoma Steel and St. Marys Paper effluents.

Parameter	MDL	Algoma Steel: 30" Blast Furnace	Algoma Steel: 60" Blast Furnace	Algoma Steel: Bar & Strip Lagoon	Algoma Steel: Terminal Basins	St. Marys Paper
Oil and Grease	1.0 mg/L	3.7 (ND-40.0)	3.6 (ND-50.0)	8.3 (ND-581)	7.6 (ND-48)	18.4 (ND-720)
Ammonia	0.5 "	27.17 (ND-1,060)	0.100 (ND-1.060)	1.356 (ND-5.30)	7.481 (ND-16.50)	0.078 (ND-720)
Suspended Solids	0.1 "	52.19 (2.10-353)	30.48 (1.90-557)	12.85 (3.50-59.4)	26.04 (2.4-121)	190 (1.8-2150)
Cyanide	0.001 "	0.028 (ND-0.590)	0.025 (ND-2.00)	0.545 (ND-2.60)	0.106 (ND-0.90)	0.004 (ND-0.02)
Total Phenols	0.2 ug/L	473 (0.4-29,000)	3.06 (.20-28.4)	15.5 (0.40-144	395 (1.20-8750)	20.8 (0.6-374)
Iron	0.05 mg/L	8.53 (0.55-200)	5.20 (ND-140)	1.95 (ND-43.0)	6.01 (0.36-64.0)	1.36 (0.27-15.0)
Lead	0.01 "	0.038 (ND-0.59)	0.016 (ND-2.50)	0.076 (ND-0.82)	0.018 (ND-0.600)	0.030 (ND-0.830)
Mercury	0.01 ug/L	0.514 (ND-19.0)	- 0.016 (ND-.230)	0.009 (ND-.050)	0.045 (ND-.700)	0.018 (ND-.050)
Zinc	0.005 mg/L	0.168 (0.007-5.00)	0.039 (ND-1.00)	0.821 (.10-13.00)	0.021 (ND-.500)	0.063 (.005-.740)

ND = Not Detected at method detection limit (MDL).

Data from St. Marys River MISA Pilot Study, twice-weekly grab sampling, March 2 1987 to March 28 1987 (approximately 100 samples).

pilot site investigation data (3,547 kg/d). The reason for this variability is unknown. The East End WWTP had the second highest loading of oil and grease (350 kg/d) during the UGLCCS survey.

The Terminal Basins and the Bar and Strip Lagoon discharges of Algoma Steel were the principal sources of ammonia during the UGLCCS survey, contributing an average of 5,960 kg/d and 210 kg/d, respectively. The average ammonia loading from Algoma during this survey (5,254 kg/d) was higher than loadings based on the 1986 annual self monitoring data which indicated an annual average of 3,990 kg/d and the August 1986 average of 2,490 kg/d.

The average suspended solids (SS) loading to the St. Marys River during the UGLCCS survey was 10,274 kg/d. Approximately 8,000 kg/d was discharged by industrial and municipal facilities. Algoma Steel had the highest SS loading (4,234 kg/d), of which the Terminal Basins contributed 3,950 kg/d. This load was well below the average SS load from the Terminal Basins as estimated from the 1986 annual self monitoring data (7,790 kg/d), and the load based on August 1986 self monitoring data (6,640 kg/d). Based on the UGLCCS data, the Terminal Basins' effluent met the Amending Control Order limits required by March 31, 1990. However, self monitoring data indicate that the loads were above this limit as well as the current Control Order limit (7,355 kg/d).

St. Marys Paper contributed an average SS load of 2,830 kg/d, the second highest. Although effluent concentrations exceeded the Ontario Industrial Discharge Objective of 15 mg/L, St. Marys Paper was in compliance with their Certificate of Approval. Suspended solids loadings from the paper plant have declined steadily since 1968 (Table VI-19).

The average total phenols loading to the St. Marys River during the August 1986 UGLCCS survey was 11 kg/d. Algoma Steel contributed 9.0 kg/d, of which 8.2 kg/d was discharged from the Terminal Basins. The Point Source Workgroup Report (49) considered the measured loading from the Terminal Basins to be quite atypical and not representative of the true loadings when compared with Algoma's 1986 annual self monitoring data (95.7 kg/d). Loadings of total phenols to the St. Marys River from Algoma Steel, using Algoma's data and the MISA pilot site investigation data were 97 kg/d and 114 kg/d, respectively. St. Marys Paper had the second highest total phenols loading during the UGLCCS survey (0.7 kg/d). Average concentrations of total phenols measured in the Terminal Basins' effluent and St. Marys Paper final effluent exceeded the Ontario Industrial Discharge Objective of 20 ug/L.

During the UGLCCS survey, 17 PAHs were measured in the effluents. An average of 0.691 kg/d of total PAHs was discharged during the survey. The highest average loading of total PAHs was from the

TABLE VI-19

Historical summary of loadings to the St. Marys River (kg/d).

Parameter	1968	1973	1983
St. Marys Paper			
Total suspended solids	23,800	13,400	3,400
BOD_5	68,800	5,600	5,300
Sault Ste. Marie, Ontario East End WPCP[1]			
BOD_5[2]	2,146	2,150	3,500
Total dissolved solids	14,220	18,227	-
Total phosphorus	-	163	194
Total kjeldhal	-	1,000	-
Nitrate	-	10	-
Ammonia	-	700	-
Chlorine	-	2,500	-

1 Water Pollution Control Plant.
2 Five-day biochemical oxygen demand.

East End WWTP (0.417 kg/d). However, this average was skewed by high results on the first day of sampling, presumably due to an industrial spill to the sanitary sewer system. On the remaining 5 days of the survey those compounds were not found, indicating that, under normal conditions, PAHs would not be detected at 1.0 ug/L in the East End WWTP effluent. During the August 1986 survey, an average of 0.2 kg/d total PAHs was discharged by Algoma Steel. All PAH compounds analyzed for were detected in the Algoma Steel coke plant effluent which discharges to the Terminal Basins. However, only 3 compounds were detected in the Terminal Basins' effluent and only at trace concentrations, close to the analytical detection limits. As with other loading data presented thus far, there is substantial variability in calculated PAH loadings from Algoma Steel. Based on the MISA pilot site data, an average of 1.14 kg/d total PAHs was discharged from the Terminal Basins alone.

Total phosphorus loads during the UGLCCS survey were greatest from the Sault Ste. Marie, Ontario East End WWTP, averaging 90 kg/d. Effluent concentrations from this primary treatment facility exceeded the GLWQA objective of 1 mg/L. Historical data presented in Table VI-19, indicate that total phosphorus loadings from the East End WWTP increased from 1968 to 1983, probably due to overloading the system because of population growth. This problem may be alleviated by the new West End WWTP which came online in 1986.

Comparisons of the point source loadings during the UGLCCS survey (Table VI-17) indicates that Algoma Steel had the highest loading of oil and grease (9,441 kg/d), ammonia (6,254 kg/d), suspended solids (4,234 kg/d), chloride (18,885 kg/d), cyanide (72.9 kg/d), total phenols (90 kg/d), total metals (4,535 kg/d), total volatiles (1.95 kg/d) and chlorinated phenols (2.69 kg/d).

In the Algoma complex, the Terminal Basins' outfall is the major source of pollutants, followed by the Bar and Strip Lagoon for lead, zinc and cyanide (Table VI-20). The Terminal Basins effluent comprises about 80% of Algoma Steel's effluent flow. Yearly trends in the Terminal Basins effluent quality (Figure VI-25) indicate a steady decline in ammonia, cyanide and phenols during the last decade. These trends are based on data collected through Algoma's self-monitoring program.

During the August 1986 UGLCCS survey, the Sault Ste. Marie, Ontario, East End WWTP had the highest loadings of total phosphorus (89.9 kg/d), mono and dichloramine (2.64 kg/d), and chlorinated benzenes - chloroethers (0.341 kg/d). The East End WWTP was also the second highest contributor of oil and grease (350 kg/d), ammonia (196 kg/d), chloride (2,011 kg/d), total metals (47 kg/d), volatiles (1.06 kg/d), PAHs (0.42 kg/d) and chlorinated phenols (1.31 kg/d).

TABLE VI-20

Loading summary of Algoma Steel effluents to the St. Marys River (kg/d).

Parameter	MDL		30" Blast Furnace	60" Blast Furnace	Bar & Strip Lagoon	Terminal Basins
Flow m3/d			22,100	67,980	80,395	315,900
Oil and Grease	0.1	mg/l	N	N	9.9	9,488
Ammonia	0.1	"	N	8.3	290	5,956
						(3090)@
Total Phosphorus	0.1	"	ND	4.5	ND	15.5
Suspended Solids	1.0	"	ND	N	347	3,946
						(7790)@
Chloride	0.5	"	504	759	6,726	10,895
Cyanide	0.001	"	4.9	9.6	89.9	28.4
Total Phenols	1.0	ug/l	NA	NA	0.8	8.16
						(95.7)@
Copper	0.005	mg/l	0.147	0.136	N	N
Iron	0.005	"	12.8	48.7	507	1,178
						(1685)**
Lead	0.005	"	ND	0.68	2.93	2.6
Mercury	0.025	ug/l	N	0.002	0.007	0.003
Zinc	0.005	mg/l	0.33	2.1	28.8	3.2
Xylene	1.0	ug/l	N	N	ND	0.415
Styrene	1.0	"	ND	ND	ND	0.084
Benzene	1.0	"	ND	ND	ND	1.12
Chloroform	1.0	"	0.002	ND	0.0014	ND
Methylene Chloride	1.0	"	0.013	N	0.019	0.107
Toluene	1.0	"	N	N	ND	0.277
2,4,6-Trichlorophenol	2.0	"	ND	ND	ND	1.48
2,4-Dimethylphenol	2.0	"	N	N	0.367	0.892
Total PAHs	1-2.0	"	0.007	0	0.024	0.157
			(0.038)**	(0.006)**	(0.022)**	(1.14)**
1,4 Dichlorobenzene	1.0	"	N	N	0.02	0.135

N = Negative Net Loading, ND = Not Detected, NA = Not Applicable, MDL = Method Detection Limit

** June 1986 OMOE MISA pilot site investigation (MDL=10 ng/L).
@ 1986 average self monitoring program of Algoma Steel.

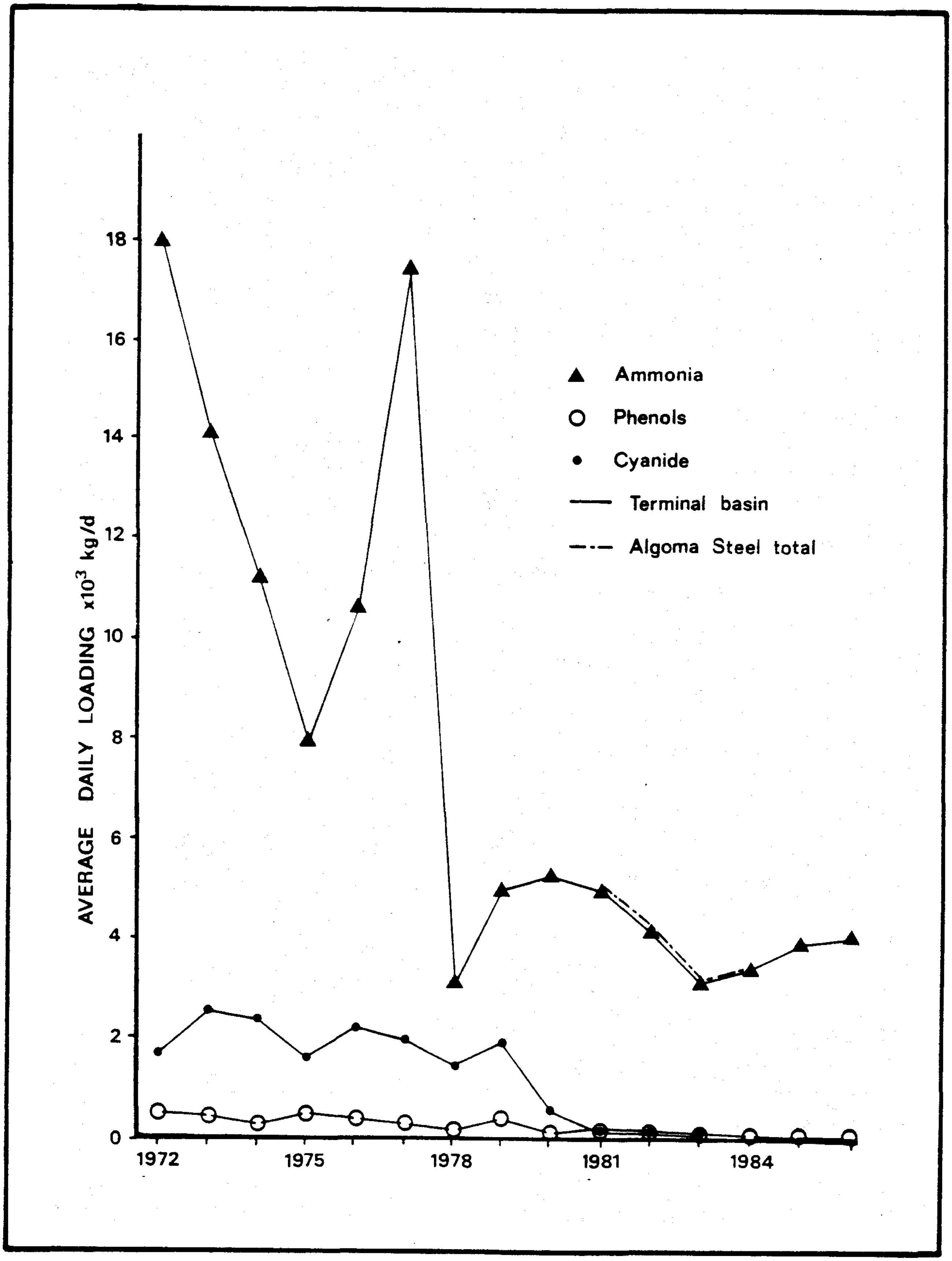

FIGURE VI-25. Annual average daily loading from Algoma Steel.

No loadings were obtained for the Sault Ste. Marie, Michigan Wastewater Treatment Plant (WWTP) for 1986 as the plant was being upgraded. Average suspended solids, total phosphorus and BOD loadings calculated from the facility's monthly operating reports (November 1986 to October 1987) were 47.3 kg/d, 6.3 kg/d and 53.6 kg/d, respectively. For the period of June 1987 to June 1988, inclusive, the reported average monthly loading (and ranges) for these three parameters were 79.9 (27.7 - 303), 13.6 (4.6 - 11.4) and 58.4 (11.5 - 102) kg/d, respectively with flows averaging 10,754 (6,232 - 15,390) m^3/d.

In general, the three Ontario tributaries (East Davignon, Fort and Bennett Creeks) do not appear to be significant sources of industrial contaminants to the St. Marys River when compared to the other sources. However, East Davignon Creek had the highest loadings for all parameters monitored. Total PAH loadings from East Davignon Creek (0.04 kg/d) during the 1986 MISA pilot study were comprised mainly of benzo(k)fluoranthene, dibenzo(a,h)-anthracene, fluoranthene, pyrene, indeno(1,2,3-c,d)pyrene and benzo(g,h,i)perylene. These compounds are related to the Algoma Steel operations. Although total PAH loadings from Bennett Creek in 1986 were an order of magnitude lower than from East Davignon Creek, the detection of coal tar in this creek during 1987 indicates the potential for additional inputs from this area.

2. Nonpoint Sources

Nonpoint pollutant loads are more difficult to assess than point sources. Nonpoint source pollutant loads are introduced into the environment from diffuse sources which enter the water system through a wide range of pathways. Furthermore, nonpoint pollutant loads are dependent on many uncontrollable natural phenomena such as rainfall, wind events, soil types and geological conditions. Due to the nature of nonpoint source pollutant loads, assessment of their magnitude and impacts is often difficult.

Urban Runoff

i) Michigan

The City of Sault Ste. Marie, Michigan has a combined storm and sanitary sewer system with ten Combined Sewer Overflows (CSOs) at the Edison Sault Electric Company Power Canal and along the river. A study completed in 1978 indicated that there were no adverse impacts from these CSOs on river water quality. The WWTP has since been upgraded and expanded (1986) and impacts are therefore expected to be minimal. However, the presence of CSOs indicates the occurrence of sporadic loadings to the river. Also, there are 8 storm drains discharging into the St. Marys

River, 15 to Edison Sault Electric Company Power Canal, and 11 to three minor tributaries (Seymour Creek - 2; Ashmun Creek - 7; and Mission Creek - 2). No loading estimates are available.

ii) Ontario

Surface drainage in the City of Sault Ste. Marie is provided by storm sewers which discharge either directly into the St. Marys River or into one of several creeks draining into the river. Stormwater also enters the sanitary sewer system and has caused hydraulic overloading of the Sault Ste. Marie East End WWTP. Three stormwater outfalls were sampled (50) in each of the subareas (residential, industrial and commercial) as shown in Figure VI-26. The mean concentrations of measured parameters are summarized in Table VI-21.

A methodology for estimating loadings of contaminants has been developed and applied to the City of Sault Ste. Marie, Ontario (50). Annual contaminant loading estimates (Table VI-22) were obtained by multiplying the annual flow volumes by the mean concentrations. The loading calculations were done separately for the land use types studied and the total loading was obtained as the sum of individual components. A summary of total stormwater loadings to the St. Marys River is given in Table VI-23, and where applicable, the low and high estimates are given.

In terms of loading magnitudes, there is a great deal of consistency among all three subareas. In general, the loadings can be ranked in a descending order as follows: chloride, iron, oil and grease, ammonia, phosphorus, lead, zinc, copper, nickel, phenols, PAHs, cyanide, cadmium, cobalt, Hg, PCBs (total), HCB.

Rural Runoff

i) Michigan

The St. Marys River geographic area encompasses 203,546 ha with the predominate land use being forest (73%). Wetlands cover 11% of the area, while cropland accounts for 11% of the land use. Due to the agricultural base of Chippewa County, the nonpoint source pollutants of concern are sediments, nutrients and pesticides.

Estimated annual soil erosion for the St. Marys River geographic area is 173,889 tonnes. The total estimated soil loss included wind, sheet and rill erosion categories. It does not include cropland ephemeral gully erosion which has been documented to be a significant source of erosion in some flat-lying areas in the State of Michigan. Nonirrigated cropland erosion accounts for 100% of the total estimated erosion.

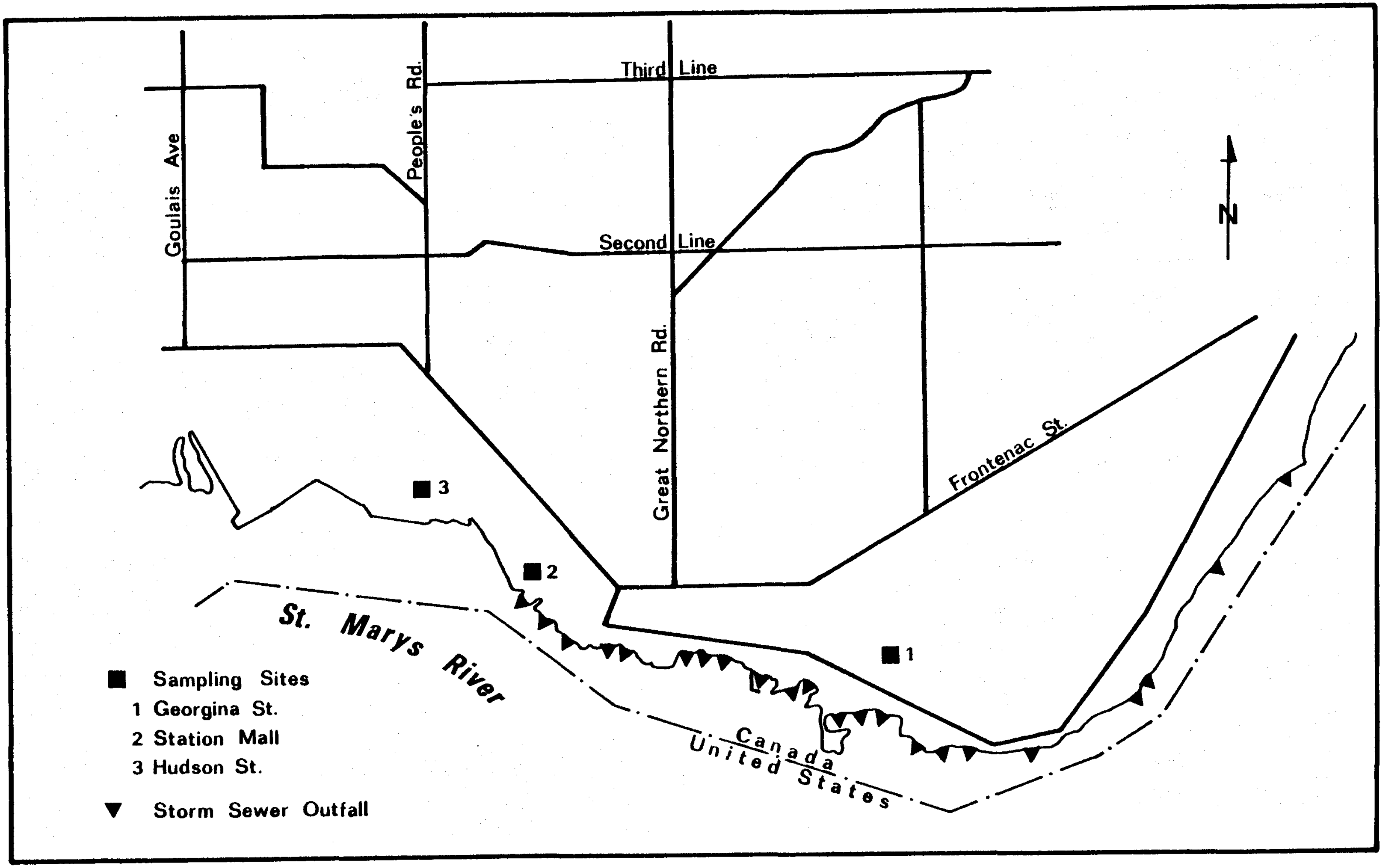

FIGURE VI-26. Storm sewer outfalls and sampling locations in Sault Ste. Marie, Ontario.

TABLE VI-21

Mean concentrations observed in urban runoff in Sault Ste. Marie, Ontario.

Parameter	Units	MDL	Stormwater Residential	Stormwater Commercial	Stormwater Industrial
Ammonia (N)	mg/L	0.001	0.87	0.42	0.49
Total Phosphorus	"	0.001	0.36	0.23	0.17
Chloride	"	0.050		1421	
				2851	
Cadmium	"	0.001	0.00	0.0011	0.00
			0.009	0.008	0.009
Cobalt	"	0.001	0.00	0.0062	0.00
			0.02	0.00	0.02
				0.02	
				0.00352	0.031
Copper	"	0.001	0.042	0.063	8.3
Iron	"	0.020	5.8	11.4	0.16
				0.21	0.000030
Lead	"	0.001	0.09	0.000013	0.000033
Mercury	"	0.00002	0.000032	0.000021	0.003
Nickel	"	0.001	0.012	0.014	0.021
			0.027	0.024	0.21
Zinc	"	0.001	0.29	0.29	2.6
Oil & grease	"	0.1	2.5	2.6	0.0100
Phenols	"	0.001	0.0165	0.0120	0.0030
Cyanide	"	0.010	0.0017	0.0027	0.00
HCB	ng/L	0.4	0.23	0.15	0.40
			0.43	0.42	-
OCS	"	1.0	-	-	13
Total PCBs	"	9.0	26	40	3,000
17 PAHs	"	50	11,500	4,700	3,500
			23,900	5,100	

1 Equivalent mean concentration.
2 Mean of concentrations detected in all three subareas.

Note:

At some sites large variations in concentrations of specific compounds were observed and/or a significant percentage of data was below the detection limits and for that reason two estimates, low and high, are given.

TABLE VI-22

Summary of loadings in urban runoff from the Sault Ste. Marie, Ontario area.

Parameter	Total Stormwater (kg/yr)	Total Stormwater (kg/d)
Ammonia (N)	9,800	26.8
Phosphorus	4,100	11.2
Chloride	1,850,000	5,068
	3,700,000	10,137
Cadmium	2.0	.0055
	78.0*	.0214
Cobalt	0	0
	263(46)*	0.721
Copper	572	1.57
Iron	92,100	252.3
Lead	1,550	4.25
Mercury	0.4	0.0011
Nickel	144	0.395
	338	0.926
Zinc	3,660	10.03
Oil & grease	33,300	91.2
Total Phenols	196	0.537
Cyanide	27	0.074
HCB	0.002	5.48×10^{-6}
	0.006	16.43×10^{-6}
Total PCBs	0.4	.0011
	3.2	.009
17 PAHs	122	.334
	238	.652

* Loadings calculated from data above the detection limit

Note:

At some sites large variations in concentration and/or a significant percentage of the data was below the detection limit and thus two loading estimates, low and high are given.

Daily loadings have been calculated assuming that annual loadings were uniformly distributed throughout the year.

TABLE VI-23

Loading summary of nonpoint source discharges to the St. Marys River (kg/d).

Parameter	Urban Runoff Ontario	Rural Runoff Michigan (livestock & soil erosion)	Atmospheric Deposition Ontario	Groundwater Michigan
Flow (m3/day)	35,077			184,150
Oil and grease	91.2			
Ammonia	26.8			
Total phosphorus	11.2	6.36		
Suspended solids				1,400
Chloride	5,068-10,137			
Cyanide	0.074			
Total phenols	0.537			
Copper	1.57			
Iron	252			
Lead	4.3			
Mercury	0.0011			
Zinc	10.03			
Xylene				
Stryene				
Benzene				
Chloroform				
Methylene chloride				
Toluene				
2,4,6-Trichlorophenol				
2,4-Dimethylphenol				
Total PAHs(16)	0.334-0.652		0.247	
Di-n-octylphthalate				
1,4-Dichlorobenzene				
Mono & Dichloramine				

Major sources of nutrients, in particular phosphorus, within the St. Marys River drainage area are fertilizer (commercial or manure spreading), livestock operations and soil erosion. It is estimated that a total of 5.18 tonnes of phosphorus are delivered per year to the water resources from livestock operations while soil erosion annually contributes approximately 1.18 tonnes of phosphorus to the water resources. A comparison of sources of phosphorus indicates that soil erosion contributes approximately 19% of the volume contributed by livestock operations and soil erosion. No estimates of pesticide loadings to the St. Marys River have been made.

ii) Ontario

No estimates of loadings from rural runoff are available for Ontario.

3. Atmospheric Deposition

Michigan

There are no estimates of atmospheric deposition available for the Michigan area for any of the UGLCCS parameters.

Ontario

Estimates of atmospheric loadings were attempted only for PAHs. Boom and Marsalek (51) collected 20 snowpack samples located in a grid centred around the City of Sault Ste. Marie, Ontario in order to establish the areal distribution of PAH depositions (Figure VI-27).

The areal distribution of PAH loadings in the snowpack tends to indicate that industrial emissions are the main source of PAHs to this area, with the highest loadings observed immediately downwind from the steel plant. Chemical finger printing indicated that the westerly stations were dominated by steel plant emissions, with the easterly stations being influenced by the other urban sources. The total quantity of PAHs stored in the snowpack in the study area was estimated to be about 18 kg for the 11 week accumulation period. PAHs stored in the snowpack are quickly released during the snowmelt period and thereby create a shock loading on the receiving waters (52). The average concentrations of total PAHs in fully mixed meltwater from the study area was estimated to be about 3 ug/L.

Although the data base refers to winter conditions, in industrial urban areas there are no seasonal variations in PAH depositions (53). Hence, the annual PAH loading extrapolated from the 2.5 month accumulation would be nearly 90 kg/yr. Based on this

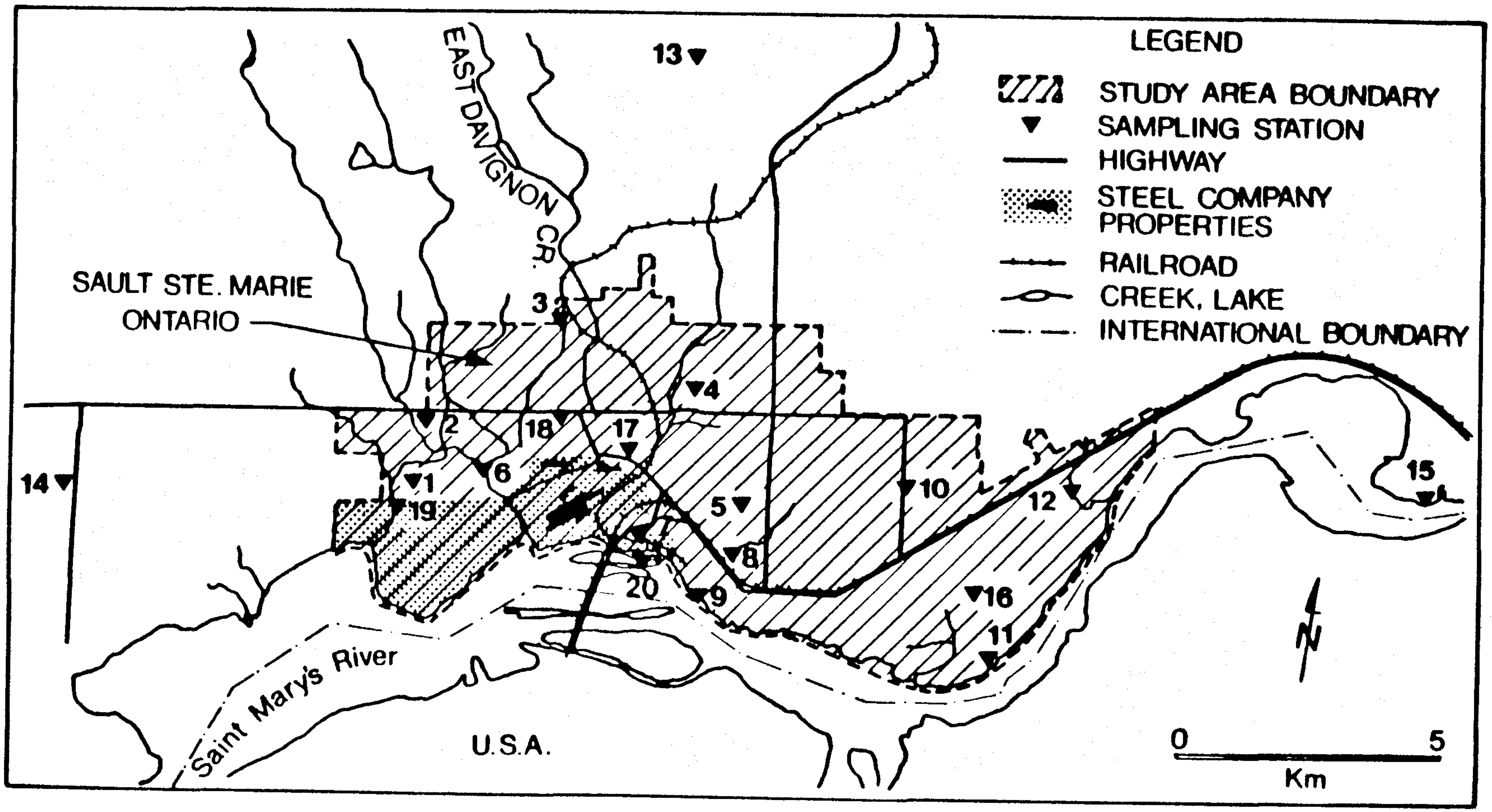

FIGURE VI-27. Snowpack PAHs sampling grid in Sault Ste. Marie, Ontario.

annual loading, estimates of annual atmospheric deposition rates for the most common PAHs found in the snowpack ranged from 13.6 - 21.8 kg/yr for phenanthrene; 17.2 -27.1 kg/yr for fluoranthene; 10.4 -16.9 kg/yr for pyrene; 1.5 - 5.2 kg/yr for both benzo(a)-pyrene and benzo(b)fluoranthene; and 2.2 - 5.7 kg/yr for benzo-(k)fluoranthene.

4. Contaminated Sediments

Studies have shown that polluted sediments have a direct impact on associated biota (29) and can be significant sources of contaminants to both the water column and aquatic organisms (31). Furthermore, such sediments can continue to be a source long after the external inputs (point and nonpoint) have been eliminated (31). However, the actual amounts of contaminants released from the sediment to the water column and organisms of the St. Marys River have not been quantified.

5. Groundwater Contamination/Waste Disposal

<u>Michigan</u>

Groundwater movement was investigated in an area extending 19 km inland along the St. Marys River from Whitefish Bay to Neebish Island. An inventory of active and inactive waste sites within 19 km of the St. Marys River was conducted as part of this investigation (19). Groundwater in the St. Marys River study area flows radially towards the St. Marys River. Total Michigan groundwater discharge directly to the St. Marys River is 2,156 L/s and contributes about 1,400 kg/d chloride (Table VI-23). Groundwater discharge from outside these areas contributes to the stream flow of the tributaries. Groundwater within the study area contributes about 47 percent of tributary flow.

Twelve sites of known, or potential groundwater contamination in the study area were identified and ranked. The majority of sites are solid waste landfills, storage sites and spills. Ranking of sites was based on their potential for contributing contaminants directly to the St. Marys River via groundwater by evaluating the hydrogeology, nature of waste material, and the distance to the St. Marys River.

One round of samples for analyses were collected from four wells installed by the United States Geological Survey (USGS) and three private wells. Some wells sampled by USGS were down-gradient from waste or spill sites including a well down-gradient from the Cannelton Industries Tannery waste site. Other locations were chosen to provide background information.

Organic compounds were generally less than their limits of analytical detection. Phthalate esters were detected at Cannelton Industries Tannery disposal site and downgradient from the Sault Ste. Marie disposal site (Union Carbide). It is possible, however, that the phthalates were related to shipping or laboratory contamination.

All samples exceeded GLWQA specific objectives and PWQO for zinc and total phenols and most exceeded the PWQO for phosphorus. Several other samples exceeded U.S.EPA AWQO for acute and chronic effects for mercury, lead and zinc. U.S.EPA Drinking Water Maximum Contaminant Levels were generally not exceeded except at the well at Cannelton Industries for chromium (primary standards) and iron and zinc (secondary standards).

Trace metal concentrations are based on nonfiltered well water and are probably not reflective of groundwater that discharges to the St. Marys River which is believed to be free of fine particulates. Thus, computation of loadings to the St. Marys River of chemical substances transported by groundwater is not currently feasible.

Local impacts on the water quality of the St. Marys River are posed by only one site in Michigan: Cannelton Industries Tannery disposal site. Impacts on the St. Marys River due to this site may occur through a combination of groundwater discharge, surface runoff, and erosion of contaminated soils and waste into the river.

State and federal regulatory file data indicate that high levels of chromium and other metals exist at the Cannelton Industries Tannery site. Down-gradient movement of contaminated groundwater from this site was detected by analyses of the well water. A remedial investigation/feasibility study has been initiated at this site under Superfund authorization.

Potential minor impacts on St. Marys River water quality are posed by the Sault Ste. Marie Disposal (Union Carbide) waste lime pile located near the river. This site is also known to contain cyanide contaminated wastes. The Superior Sanitation Landfill (3 Mile Road), containing municipal and light industrial refuse as well as sludges from the Sault Ste. Marie WWTP, is another potential source to the river.

<u>Ontario</u>

Two waste disposal sites were identified in Ontario. The Algoma Steel Slag Site was characterized as having a definite potential for impact on human health and safety. At this site, approximately 718,600 tonnes of solid waste and 66,800 tonnes of liquid waste are disposed each year. The predominant waste is slag from iron and steel operations. However, lime, industrial refuse, waste acid and oil, coke oven gas condensate, and sludge are also disposed on the site.

Detailed hydrogeological investigations at the Algoma Steel Slag Site have established that groundwater flows toward the St. Marys River, either directly, or indirectly by discharge to the Algoma Slip. High hydraulic conductivities in surficial slags and sands suggest rapid groundwater flow. Several investigations have documented groundwater and surface water contamination with metals, ammonia, cyanide, and PAHs which may be associated with this site. Work completed to date on the Algoma Slag Site has not conclusively proven the significance nor the magnitude of contaminants migrating off the site and impacting on adjacent groundwater, surface waters or biota. In early 1988, OMOE initiated a two year intensive study to quantify loadings and impacts associated with leachates from the site.

The other site in the area, the Sault Ste. Marie (Cherokee) Landfill is believed to have a negligible impact on surface waters of the St. Marys River. This landfill is licensed to handle municipal waste composed of 60% domestic waste (200 tonnes/d), 10% commercial waste (35 tonnes/d) and 30% sewage sludge (100 tonnes/d).

As summarized in Table VI-23, the majority of data on nonpoint source loadings is for urban runoff in Ontario. Therefore, few comparisons can be made between this source and other nonpoint sources of pollutants to the St. Marys River.

6. Navigation

The average number of vessels passing through the locks has decreased from 26,122 vessels in 1953 to 12,712 in 1970, and to 8,345 in 1986. The vessels carry mainly crude oil, grain, steel, coal, petroleum products, taconite and iron ore between Lake Superior and the industrial centres on the lower lakes.

Significant enhancement of the primary productivity takes place immediately after tanker passage (46). These observations suggest that there is an absence of pronounced sediment-bound toxicity in the St. Marys River.

7. Spills

Spills can be a significant source of contamination to a river system and constitute a major concern. The concern is that the river may, during a short period of time, be subjected to a shock contaminant loading that may be several orders of magnitude greater than the annual loading. A summary of spills from Algoma

TABLE VI-24

Summary of spills to the St. Marys River, Canadian sources (1983-1986).

Date of Occurrence	Material/Source	Action
Algoma Steel:		
March 7, 8, 9/83	High phenols/ Terminal Basins 2,200, 1,870 3,100 ppb, respect.	Cooler start-up No enforc. action
July 26/83	De-phenolized liquor/Tank Leak	Photos, samples tested
November 24/83	De-Phenol. liquor/pin-hole in tank/ min. quant. lost	Drained/welded/refilled
January 24/84	500-1,000 Igal HCl to Lub pit	Pumped to holding tank for re-use
December 13/84	Approx. 2,000 Imp.gal liquid tar @ #7 coke oven battery	Collected by Weldwood
January 22/85	700-1,000 ppb phenols/Terminal Basins	Operator error, operator log revised
April 17/85	75 m imp.gal/d Terminal basin discharge & stormwater drift across the river	Investigated & complaint verified
August 11/86	Process wastes (iron, SS)/Terminal Basins	Overflow due to rainfall, none recovered
August 15/86	3,200 imp.gal/d process wastewater (Fe, SS) Terminal Basins	None, no environmental impact expected
August 18/86	Ammonia, cyanide	Unknown
<u>St. Marys Paper:</u>		
July 12/86	20,000 lb H_2SO_4 to clear water sewer/tank leak	Repaired
September 13-16/85	45 imp.gal/d H_2SO_4/Tank leak	Leak plugged and tank emptied
<u>East End WPCP:</u>		
May 5/86	Raw sewage	None recovered
July 17/86	Chlorinated raw sewage	None recovered
<u>Unknown Sources:</u>		
May 28/86	Non-PCB oil	None recovered

HCl - Hydrochloric Acid
SS - Suspended Solids
H_2SO_4 - Sulphuric Acid

Steel and St. Marys Paper (Table VI-24) indicated that the spill on March 7,8 and 9, 1983 from the Terminal Basins may represent a short-term phenol loading of about 2.4 tonnes to the St. Marys River which is 1 to 2 orders of magnitude greater than the normal loading from this discharge (Table VI-20). This demonstrates a significant shock loading to the river over a short period.

Over the past 50 years there have been numerous coal tar and product spills on Algoma and Domtar properties in proximity to Bennett and Spring Creeks. The spills have been from tank overflow, pipeline breaks and process leaks. These spills have been up to 10,000 gallons or more into creeks and onto slag-filled shorelines.

In May of 1987, an oil slick was observed on Spring and Bennett Creeks. Upon further investigation, the creek beds were found to contain coal tar saturated sediments to depth in excess of .75 m and a dense oily free-phase liquid (suspected of being coal tar and/or creosote) was flowing along the surface of the sediments. Both companies were directed to remove any free-phase material from the creek bed and to install coffer dams and/or sandbags to prevent the flow of free-phase material to the St. Marys River. The companies were also directed to conduct studies to determine the extent of contamination of the creeks and adjacent soils, to determine the source(s), and to recommend remedial options to prevent further contamination of the St. Marys River.

8. Summary

Table VI-25 summarizes the relative contributions of point and nonpoint source loadings of selected organics and heavy metals to the St. Marys River. In general, the river is subject to a daily loading of 14 tonnes of suspended solids, 5 tonnes of free ammonia, 4.5 tonnes of oil and grease, and 3 tonnes of iron. Loadings of other contaminants such as PAHs, volatiles, phenol and cyanide ranged from 3 kg/d (PAH) to 117 kg/d (phenols).

The high loadings of suspended solids and oil and grease represent a major factor in the destruction of river habitat as reflected by an adversely impacted benthic community along the Ontario shoreline of the river.

Although loadings of contaminants from nonpoint sources were not sufficient to set a priority on these sources, available information indicated that up to 50% of PAHs, zinc and lead loadings to the river may be attributed to nonpoint sources.

TABLE VI-25

Loading summary of point source* and nonpoint summary to the St. Marys River (kg/d).

Source Parameter	PAHs	Volatiles	Suspended Solids	Oil & Grease	Ammonia	Lead	Zinc	Iron	Cyanide	Total Phosphorus	Total Phenols
Point Sources											
Industrial	1.25	3.1	11,090	3,810	4,395	7.4	38	2,290	74.0	25	115
Municipal	0.423	1.14	987	363	210	1.2	2.3	48	NA	102	0.53
Tributary	0.051	ND	2,224	NA	21	NA	0.94	85	0.32	3.2	0.69
Nonpoint											
Urban	0.334-0.652	NA	NA	91	27	4.3	10.0	252	0.074	11	0.54
Rural	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.4	NA
Atmospheric	0.247	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Groundwater	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL	2.621	4.24	14,301	4,264	4,653	12.9	51	2,675	74	148	118

NA - Not Available, ND - Not Detectable
* - Various data sources (Table VI-17)

D. DATA QUALITY ASSESSMENT

The OMOE data for PAHs in caged clams and surficial sediments was generated by an external contract laboratory that performed poorly in the UGLCCS round robins (Chapter IV). Consequently, this data was checked by OMOE GC/MS laboratory staff and only after their data quality concerns were addressed and the data declared qualitatively and quantitatively accurate was this information used in the report.

Some of the effluent and river water samples analyzed by the OMOE laboratory for total phenols in 1986 were flagged as possibly having been contaminated by phenolic substances due to an improper cap liner (i.e. concentrations may have been reported higher than actual). However, this data was used when subsequent sampling, during the 1987 MISA pilot site surveys, revealed similar concentrations in effluents and water.

In the Canadian point source study, the federal laboratory which analyzed PAHs had somewhat lower method detection limits (1-2 ug/L) than did the OMOE lab analyzing samples for the MISA pilot site study during 1986 (10 ng/L). Because this difference affected the quantification of PAH loadings from dischargers, the UGLCCS data set was supplemented by the MISA data.

E. PROCESS MODELING

1) Physical: Hydrodynamics, Wind, Waves and Currents

For the purpose of the modeling study, the St. Marys River has been divided into an upper reach - above the regulatory works, and a lower reach - below the regulatory works.

Upper St. Marys River

The primary factors involved in the flow distribution in the upper river are gravity, wind, bed friction and the associated pressure forces. One of the causes of water movement in the deep channels of the upper St. Marys River is the inertial forces exerted by the large inflows from Lake Superior through the narrow mouth at Pointe Aux Pins. In the localized shallows of Leigh Bay and Pointe Aux Pins Bay, an appreciable influence on the water circulation is exerted by wind stresses.

One objective of the modeling was to describe the hydrodynamics of this area using mathematical models. A three dimensional steady state finite element model was applied to this area. The mathematical formulations were based on the three dimensional equations for conservation of mass and momentum. The principal assumptions used were:

i) the pressure was assumed to vary hydrostatically;

ii) the rigid-lid approximation was made, i.e. the vertical velocity at the undisturbed water surface was assumed to be a constant value of zero;

iii) eddy coefficients were used to account for the turbulent diffusion effects (the vertical coefficient was assumed constant while the horizontal coefficients were assumed to be zero); and

iv) the dimensions of the study area were small compared to typical weather systems, so that the geostrophic wind is assumed uniform over the entire area.

The basic equations (55,56) contain three empirical constants, i.e., the vertical eddy diffusion coefficients, the wind drag coefficient and the bottom slip coefficient, which cannot be determined from theory alone but must be tuned by means of proper field data in such a way that agreement between the model and prototype is satisfactory. A sensitivity analysis involving a large number of computer runs was made for these coefficients in order to assist with the calibration process.

The model was calibrated and verified using current meter data from the following sources:

i) the U.S. Corps of Engineers;
ii) the Ontario Ministry of the Environment;
iii) Integrated Exploration Limited; and
iv) aerial photographs taken of the area.

The model indicates that the upper river is highly responsive to wind speed and direction. Its dynamic behaviour is important in the shallow bays where gyres readily form. Examples of gyres formed under no wind and north wind (19 km/hr) conditions are shown in Figures VI-28 & 29.

Some of the contaminants (e.g. PAHs) in the bays are associated with the movement of fine grained sediment particles; it is expected that the gyres will play a significant role in the transport of contaminants from the area of the slag site to Leigh and Point Aux Pins Bays. The model has indicated that up to two strong gyres can be formed simultaneously.

Combined with existing field data on current measurements in this area, the calibrated model provides a better understanding of the cause and effect relationship between the wind and the circulation patterns in the upper river. This will eventually lead to the construction of more detailed fate models for management purposes. In addition, the model may provide new insights to the complex hydrodynamics of the upper river for those who are involved in collecting field data for the area.

Lower St. Marys River

The lower river is a nonuniform natural channel with slightly over half of its width dredged to a minimum of 8.5 m for the passage of ships. The velocity field data on the lower river is available from the U.S. Corps of Engineers. The data indicate the presence of some dead zones and re-circulation zones in the river due to natural or man-made protuberances from the shoreline.

The lower river was simulated by KETOX (57). This is a model that has a steady-state depth averaged hydrodynamic submodel coupled to a convection-diffusion (mixing) submodel. KETOX model has the following features:

i) it provides a forward marching solution to the continuity and momentum equations for the river (58);

ii) it provides solution for the lateral dispersion coefficients across each cross-section of the river based on the turbulence transport equations (K and E); and

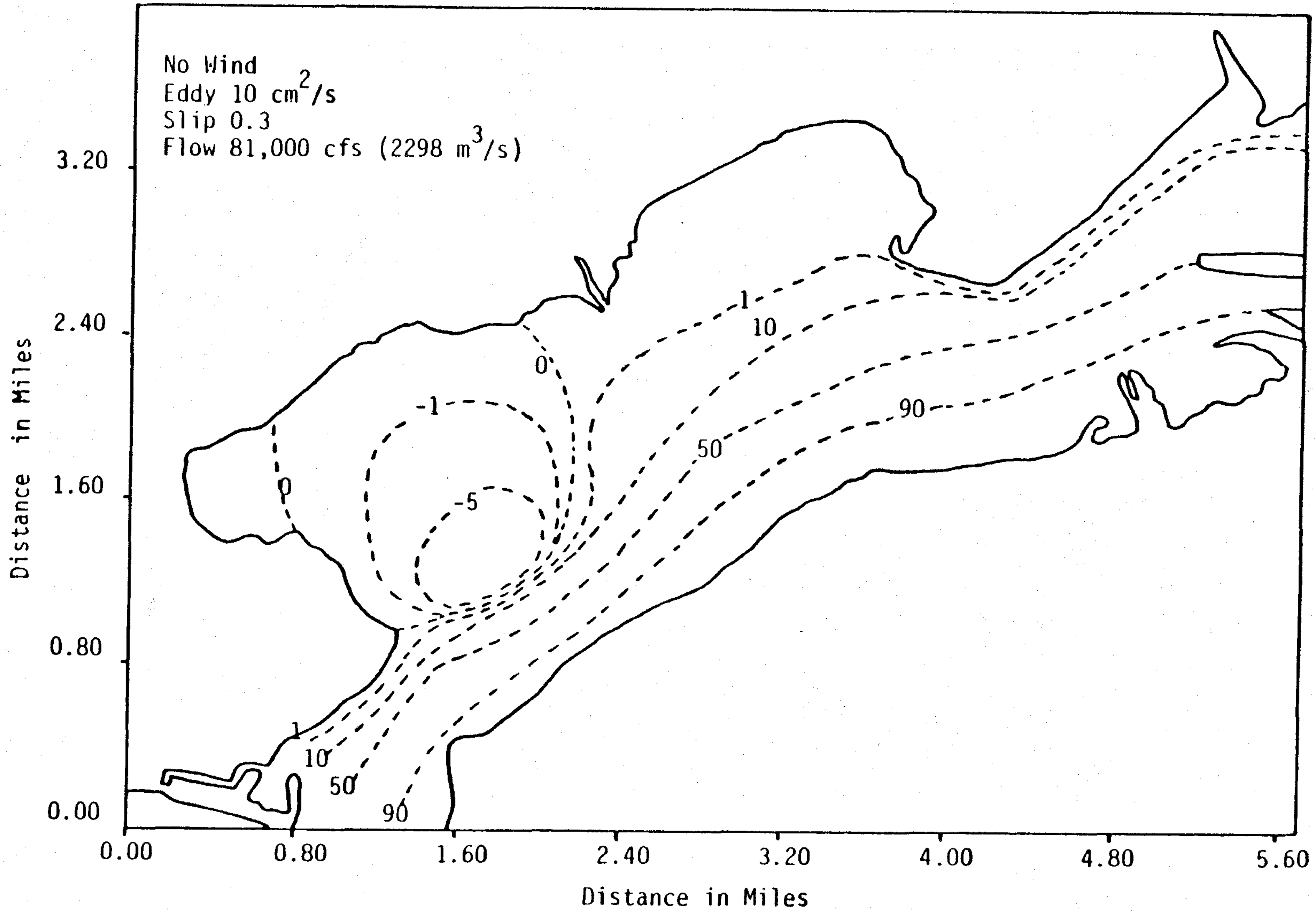

FIGURE VI-28. Dimensionless stream function circulation pattern (no wind).

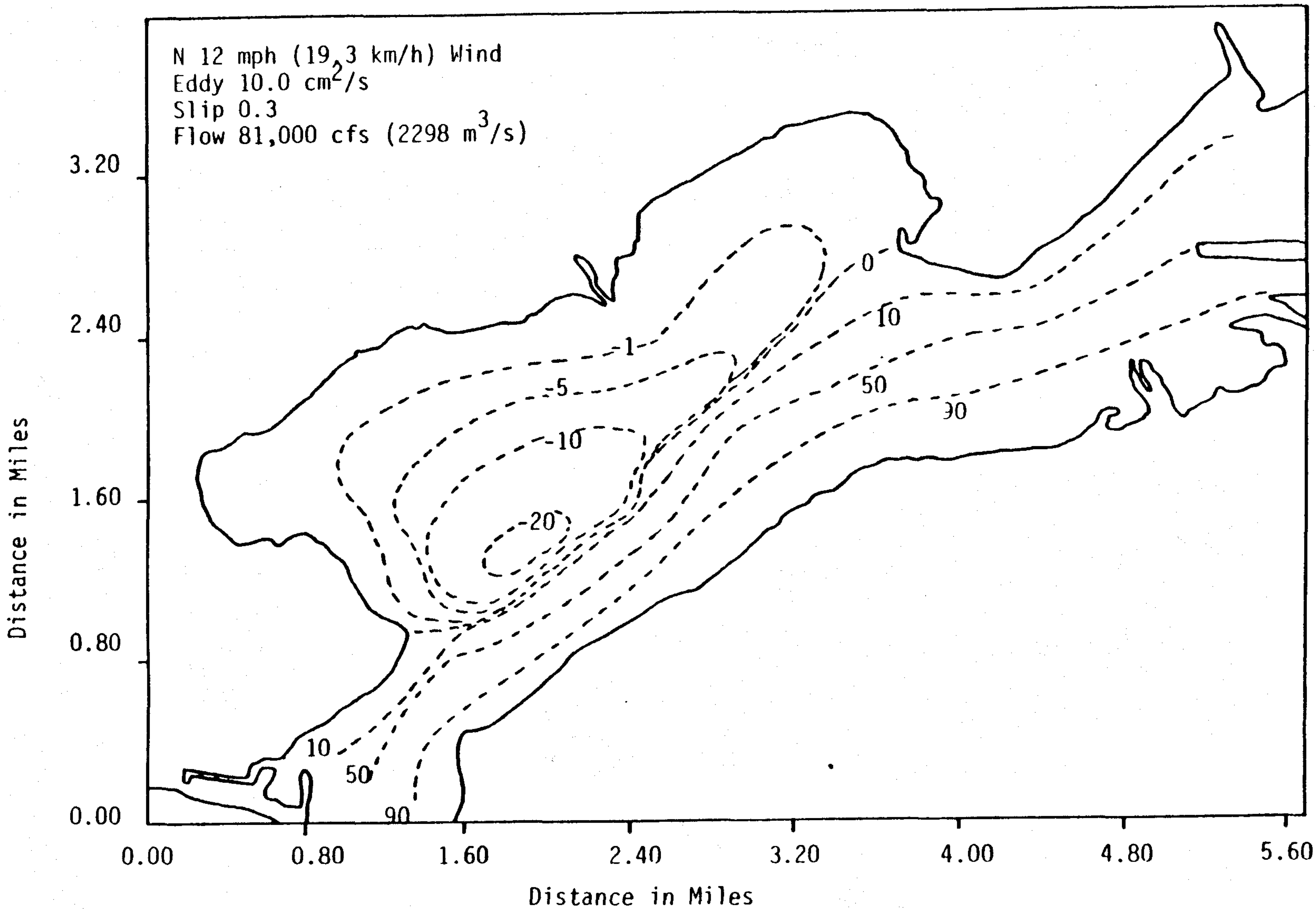

FIGURE VI-29. Dimensionless stream function circulation pattern (north wind).

iii) it can accept discharges from multiple outfalls.

The hydrodynamic component of KETOX was calibrated using U.S. Corps of Engineers (COE) 1984 field data based on current meter measurements and drogue surveys.

2. Physical-Chemical-Biological: Fate and Transport Models

The contaminant dispersion submodel of KETOX was calibrated using the 1974 OMOE phenol loadings and ambient measurements (10). The Model was subsequently verified with the 1983 OMOE phenol field data. The calibration and verification are illustrated in Figure VI-30 which is a dimensionless plot of the measured and predicted phenol concentrations along the Canadian shoreline starting from the Terminal Basins outfall location for the years 1974 and 1983.

The mixing model (K-E model) for the lower river (including the Algoma Slip and Control Structure) has been calibrated for hydrodynamics. For steady-state loading, isoconcentration maps can be developed with longitudinal resolution of the order of 15 m and lateral resolution as low as 1 % of the flow in the reach. This permits a reasonably accurate zone of effect or mixing zone to be defined so that various loading scenarios can be compared and evaluated.

Table VI-26 illustrates the longitudinal extent of the mixing zones associated with discharge from the Terminal Basins under the average summer river flow (2,450 m^3/s). The 1986 loadings for ammonia and cyanide (4,066 and 29 kg/d, respectively) will result in a mixing zone equal to or less than 100 m where the GLWQA and OMOE Water Quality Objectives are met. Also, there are no toxic effects within the mixing zone, although the effluent is toxic. The mixing zone associated with the phenol loadings from the Terminal Basins extends at least 7 km along the Ontario shore. Although the frequency of occurrence of low river flow (1.53×10^6 L/s) is about 0.1%, an estimate of the mixing zone associated with the 1986 loading is predicted to provide insight into the need for urgent reductions of phenol loadings. Figure VI-31 indicates that transboundary pollution may occur under the lowest flow possible.

Oil and grease within the bed sediment constitutes a major factor in the absence of <u>Hexagenia</u>. To model the impact of discharged oil and grease upon bed sediment, partitioning between water and sediment phases must be considered. For demonstration purposes, it is assumed that the concentration of oil and grease within the water column should not be more than 10% above the upstream background level (i.e., about 0.5 ppm). Using this guideline, the zone of effect is about 0.8 km. This same arbitrary guideline may be used for suspended solids, in order to minimize the amount of the organic portion of solids (which is responsible for most

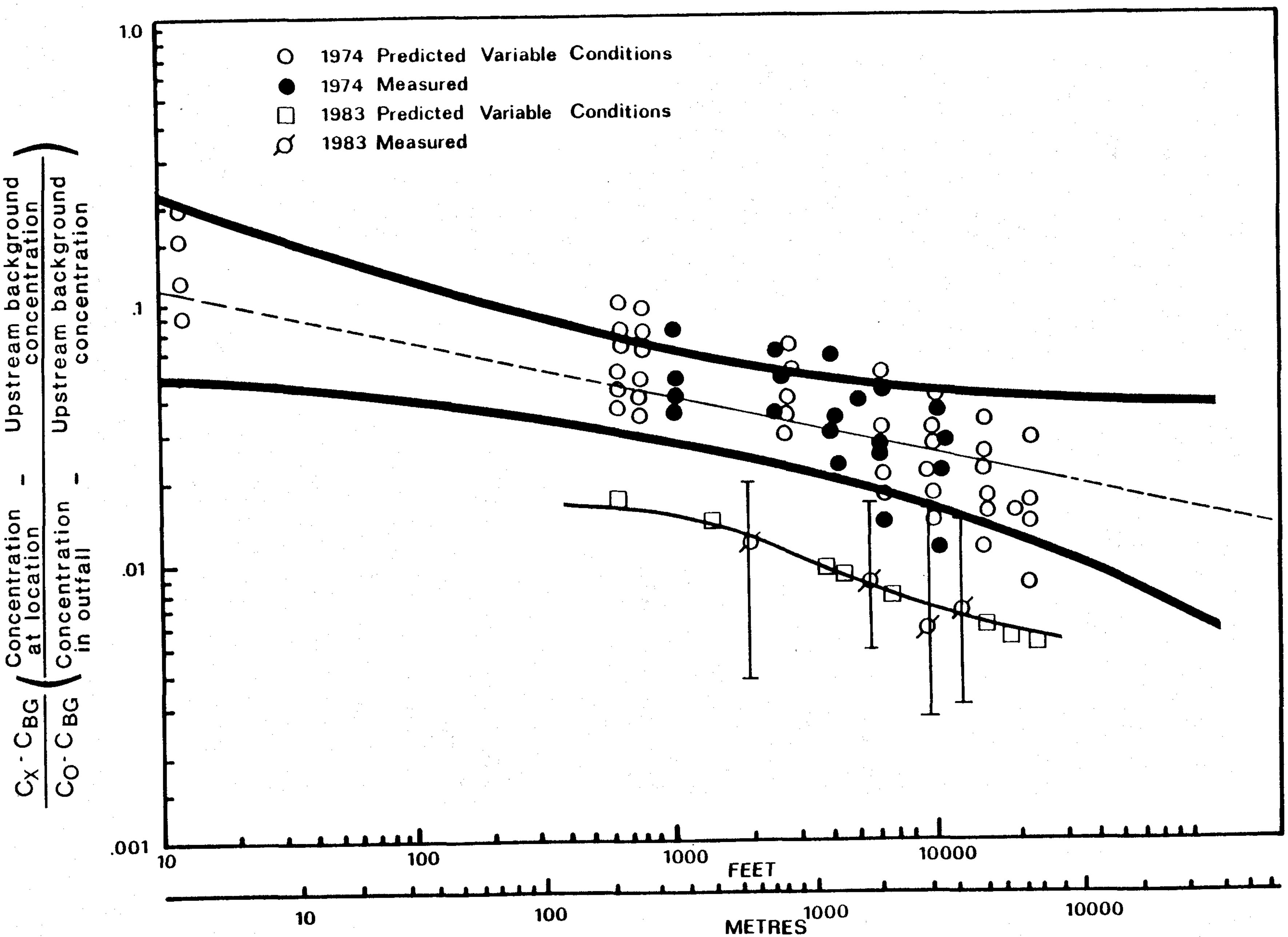

FIGURE VI-30. Predicted and measured phenol concentrations versus distance along the Canadian shoreline.

TABLE VI-26

Point source impact zone predictions from the Terminal Basins, under average summer river flow.

Parameter	1986 Loads (kg/d)	Length of Zone for 1986 Terminal Basin Loads (km)
Ammmonia	4,066*	<0.1
Cyanide	29**	<0.1
Phenol	114***	>7.0
Oil & Grease	1,413*	0.8
Suspended Solids	7,788*	7.0

Note: Loads from Table VI-19

* Average of self monitoring program of Algoma Steel
** UGLCCS data.
*** 1986 MISA Pilot Site data.

TABLE VI-27

Loadings (in kg/d) required to limit point source impact zones to 300 and 100 m from the Terminal Basins, under average summer flow (see text).

Parameter	300 m Impact Zone	100 m Impact Zone
Phenols	19	12
Oil & grease	950	590
Suspended solids	1,900	1,200

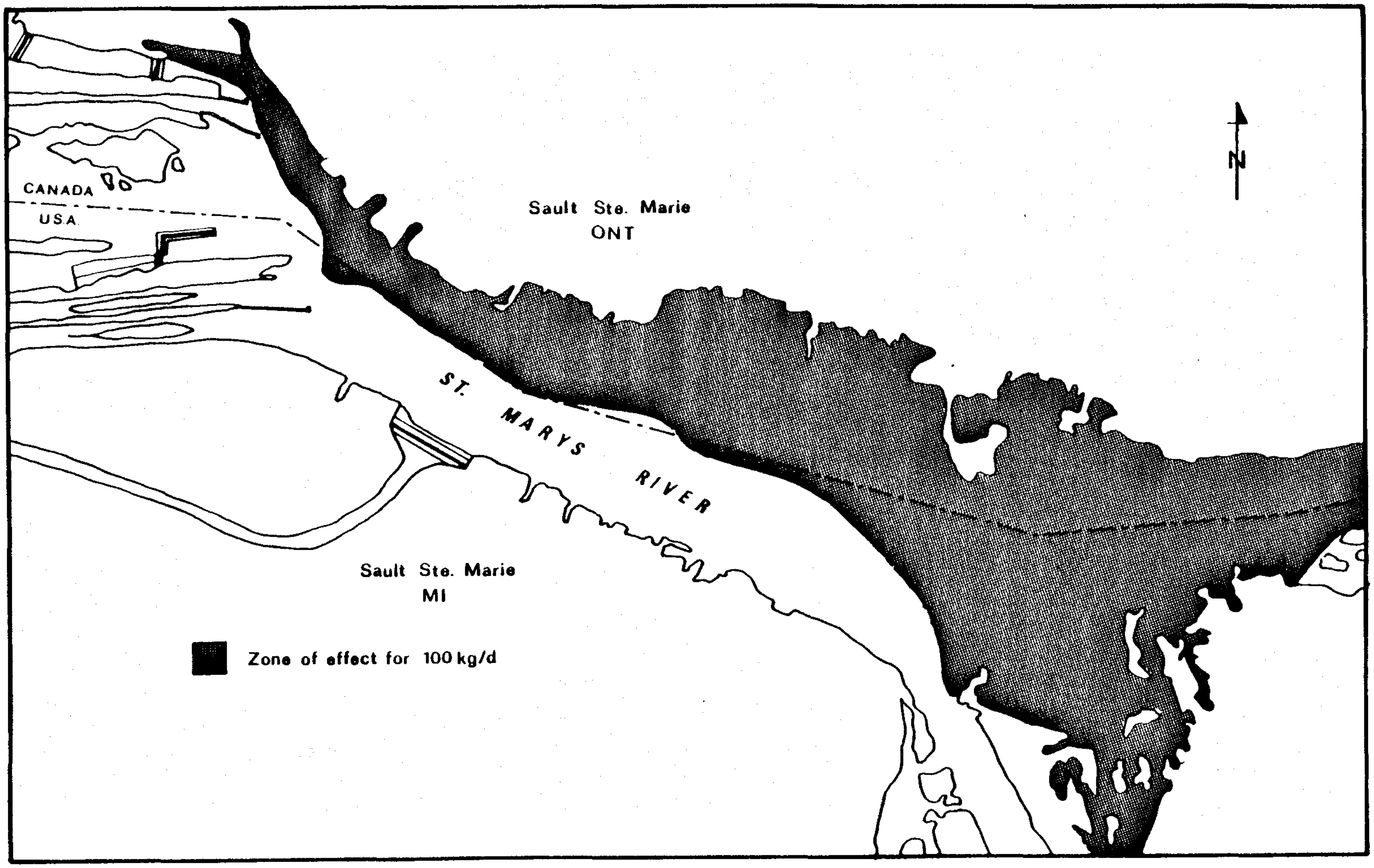

FIGURE VI-31. Zone of exceedence of phenol concentration of 0.002 mg/L for loads of 100 kg/d from the terminal basin under the St. Marys River's lowest flow conditions.

contaminants). Thus the concentration of suspended solids should not exceed about 1 ppm within the water column. This would result in a zone of effect of about 7 km.

These modeling tools may be used in a "regulatory mode" to derive the maximum effluent loads so as to meet the objectives and guidelines at selected distances downstream of any outfall. Table VI-27 summarizes these calculations for phenol, oil and grease, and suspended solids discharged from the Terminal Basins under the average summer flow in the river.

F. GOALS AND OBJECTIVES FOR REMEDIAL PROGRAMS

The goals of remedial measures in the St. Marys River should be the ultimate elimination of unacceptable adverse impacts on aquatic life and to ensure that the water is acceptable for drinking and recreation. Objectives will focus on the need to decrease the input, transport and biological availability of conventional and toxic pollutants in the St. Marys River.

Exceedences of water quality objectives are mainly restricted to a narrow band along the Ontario shore downstream of Algoma Steel and St. Marys Paper effluent discharges. Partial recovery from the effects of these inputs occurs downstream; however, discharges from the nonpoint sources (e.g. urban runoff) and the Sault Ste. Marie, Ontario East End WWTP delay complete restoration of satisfactory water quality with respect to several contaminants until Lake George.

Objective 1: **Reduce point source loadings of phenols, oil and grease, iron, phosphorus, and fecal coliform bacteria to meet water quality objectives throughout the river.**

Objective 2: **Eliminate point source impact zones downstream of each outfall through the reduction (to zero) of chronic and acute effluent toxicity.**

Although no water quality criteria exist for suspended solids, there is some indication that suspended solids and the associated contaminants may be a concern in the St. Marys River. Contaminants adsorbed onto the particulates can be deposited locally or transported long distances before settling out, thereby increasing the downstream extent of their impact.

Objective 3: **Reduce suspended solids loadings to the river.**

The full environmental significance of PAHs in the St. Marys River is presently difficult to evaluate due to insufficient data, and lack of compound specific toxicity information and standards. However, concentrations of total PAHs and selected PAHs, such as benzo(a)pyrene, were above available guidelines in river water and surficial sediments at one or more locations in the Sault Ste. Marie area. The presence of elevated levels of PAHs in caged clams introduced to the St. Marys River indicates that these compounds are potentially available to biota.

Objective 4: **Reduce PAH Point and Nonpoint Source loadings to the river.**

The benthic macroinvertebrate community in the St. Marys River is degraded along the Ontario shoreline downstream to Lake George. Generally, degraded communities exist in the vicinity of industrial discharges and in areas where sediments contain high concentrations of metals and organic contaminants. General reductions in conventional pollutant loadings from the major Ontario point sources do not appear to have resulted in proportional improvements in the health of the benthic community and may be related to occasional spills or persistent effects of contaminated sediments. The correlation of high oil and grease levels in sediments with low densities of Hexagenia nymphs indicates that reductions in the levels of oil and grease may be an important factor in the re-establishment of a healthy benthic community.

Depending on their geochemistry and organic content, polluted sediments may be a source of contaminants (e.g. heavy metals) to benthic organisms. This availability of contaminants may affect the benthic community as well as higher trophic levels.

Objective 5: **Improve the benthic macroinvertebrate community along the Ontario shoreline by reducing contaminant loadings and by the appropriate remediation of contaminated sediments.**

In addition to point and nonpoint discharges of contaminants, manmade modifications to the upper St. Marys River have resulted in changes and/or destruction of important benthic habitats and fish spawning areas (e.g. St. Marys Rapids). Currently, there is concern that human activities (e.g. aggregate reclamation) may result in further destruction of habitat due to physical removal and/or increased siltation.

Objective 6: **Prevent further benthic and fish spawning habitat degradation through the careful evaluation of proposed activities and modifications in the St. Marys River and upstream.**

G. ADEQUACY OF EXISTING PROGRAMS AND REMEDIAL OPTIONS

1. Existing Regulatory Programs (see Chapter III)

Ontario

i) Algoma Steel Operations

Table VI-28 shows Algoma's current discharge requirements. On June 13, 1983, Algoma Steel was served with an Amended Control Order aimed at controlling contaminants such as phenols, cyanide, ammonia, oil and grease and suspended solids which were found to be in contravention of Ontario's Environmental Protection Act. Since the issuance of the Control Order, Algoma's economic situation deteriorated to the point that the company could not fulfill all the Control Order requirements or dates of completion. As a result, on November 4, 1986, the Control Order was amended to extend the dates for compliance. In the spring of 1988 OMOE and Algoma negotiated ammendments to the 1986 Control Order to allow the operation of the #7 coke oven battery and to advance air emission requirements for the Algoma complex. The order was issued September 23, 1988 and included the following requirements:

Action	Deadline
- Reduce oil and grease loading to 1,023 kg/d	March 31, 1990
- Reduce total suspended solids loading to 5,108 kg/d	March 31, 1990
- Reduce phenol loading to 22.7 kg/d	June 30, 1989
- Reduce cyanide and ammonia to below level graphically illustrated by the diagonal line shown in Figure VI-32	Feb. 15, 1989

ii) St. Marys Paper

The St. Marys Mill is not subject to federal requirements because it existed prior to 1971 when the Federal Pulp and Paper Effluent Regulations were first promulgated. However, the federal limits may be used as a guideline and OMOE has incorporated the federal limit for total suspended solids (TSS) into the Certificate of Approval for the mill. This limit is based on the production rate for various unit processes, which varies from day to day.

TABLE VI-28

Comparison of point source effluent levels and permit requirements.

Current Requirements	Algoma Steel Terminal Basins	St. Marys Paper	East End WWTP	West End WWTP	Michigan WWTP
Algoma Steel (Control Order)					
Oil and grease - 1,589 kg/d	1,413*				
Suspended solids - 7,355 kg/d	6,717*				
Phenols - 22.7 kg/d (Compliance date 06.30.89)	95.7				
Cyanide + Ammonia See graph (Fig. VI-32) (Compliance date 02.15.89)	0/15 mg/L / 11.5 mg/L* toxic above limit				
St. Marys Paper (Certificate of Approval)					
Suspended solids - 10 T/d		3 T/d			
East End WPCP (Certificate of Approval)					
Suspended solids - 50% removal			65%		
BOD5 -30% removal			17%		
Phosphorus 1.0 mg/l#			2.9 mg/L		
West End WPCP (Certificate of Approval)					
Suspended Solids - 20 mg/L				4.8 mg/L@	
BOD5 - 20 mg/L				4.0 mg/L@	
Phosphorus - 1.0 mg/L				0.7 mg/L@	
Phenol - 0.01 mg/L				0.003 mg/L@	
Ammonia - 8 mg/L				1.9 mg/L@	
Chlorine - 0.5 mg/L				-	
Michigan WWTP (NPDES Permit)					
BOD5 - 30 mg/L					6.4**
pH - 6.5 to 9.0					7.2**
Suspended Solids - 30 mg/L					5.5**
Total Phosphorus - 1 mg/L					0.76**

* Based on average annual self monitoring data.
** Based on monthly operating report from November 1986 to October 1987.
@ Survey average concentration.
\# The plant is not required to meet this limit until phosphorus removal facilities come on-line.

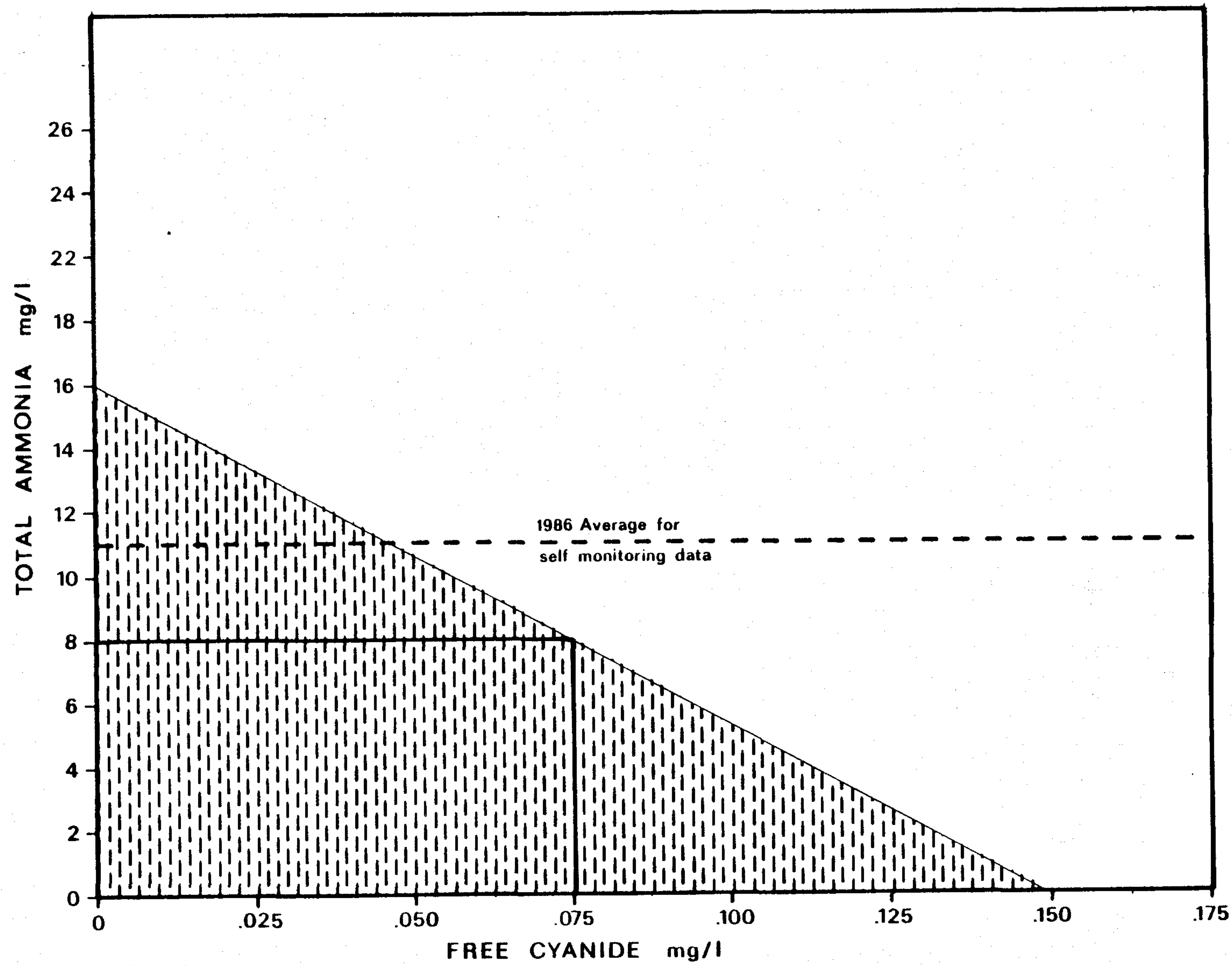

FIGURE VI-32. Algoma Steel allowable discharge concentrations of total ammonia and free cyanide from the terminal basin.

iii) Municipal Sewage Treatment Plants

Municipal WWTPs in Ontario are required to meet the general effluent limits specified by the Ministry of the Environment in OMOE Policy 08-01 "Levels of Treatment of Municipal and Private Sewage Treatment Works Discharging to Surface Waters" and OMOE Policy 08-04 "Provision and Operation of Phosphorus Removal Facilities at Municipal, Institutional and Private Sewage Works". This latter policy has not been applied to the Sault Ste. Marie East End WWTP. However, the GLWQA, Annex 3, does call for phosphorus controls of 1 mg/L on municipal waste water treatment facilities in the Great Lakes Basin with flows exceeding 3.7 x 10^3 m^3/d. A primary plant (e.g. East End WWTP) without phosphorus removal must achieve, on a annual average basis, a 30% removal of BOD_5 and a 50% removal of suspended solids (see Table III-7, Chapter III).

The West End WWTP, which is a secondary plant with phosphorus removal, is expected to meet the following Certificate of Approval requirements on the basis of arithmetic means of a minimum of 12 consecutive month analytical results from a minimum of one daily composite sample per month: BOD_5 and suspended solids, 20 mg/L; total phosphorus, 1.0 mg/L; total phenol, 0.01 mg/L; ammonia, 8 mg/L; and residual chlorine, 0.5 mg/L.

A model by-law ("By-Law to Control Industrial Waste Discharges to Municipal Sewers") was prepared by the OMOE and has been adopted by the City of Sault Ste. Marie. The by-law is intended to ensure the protection of WWTPs (including collection and disposal facilities) and to regulate the discharge of industrial wastes to municipal sewers.

The "Sault Ste. Marie Sewer By-Law" was passed in August 1968 and amended in April 1969. This by-law specifically regulates the discharge of conventional pollutants, metals and total phenols to sanitary and storm sewers. Other materials such as radioactive waste, benzene, gasoline and solvents are strictly prohibited. Cooling water or other unpolluted industrial water cannot be discharged to a sanitary sewer (City of Sault Ste. Marie, 1969).

Michigan

The effluent limitations contained in the NPDES Permit for the Sault Ste. Marie, Michigan WWTP are based upon application of regulations promulgated in accordance with the Federal Water Pollution Control Act Amendments of 1972 and the State of Michigan Water Quality Standards. The permit includes limits for BOD_5 - 30 mg/L monthly average, 45 mg/L 7-day average; pH - minimum 6.5, maximum 9.0; suspended solids - 30 mg/L monthly average, 45 mg/L 7-day average; and total phosphorus - 1.0 mg/L monthly average. From May 1 to October 15 of each year fecal coliform bacteria limits are 200/100 ml on a monthly average and 400/100 ml on a 7-day average. Effective January 1991 the 7-day average total residual chlorine in the effluent must not exceed 0.03 mg/L.

2. Actual Discharges vs. Control Requirements

Ontario

i) Algoma Steel

The levels of oil and grease and suspended solids associated with Algoma Steel's Terminal Basins discharges are periodically in excess of the Control Order's current requirements (Table VI-28). These exceedences have been referred to OMOE Investigations and Enforcement Branch for further action. The self-monitoring data indicated that discharges of cyanide and ammonia from the Terminal Basins were above the limits scheduled for February 15, 1989 (Figure VI-32). The combined effect of ammonia and cyanide discharging from the Terminal Basins constitutes toxic conditions. Bioassays on effluent samples collected from the Algoma Steel complex indicated that the Bar and Strip Lagoon effluent was the most toxic discharge to the river. The 96 hr LC_{50} for the Bar and Strip Lagoon effluent ranged from 2.2% to 100%. The Terminal Basins' effluent 96-hr LC_{50} ranged from 51% to 96% effluent in 1987. In the first quarter of 1988 the Terminal Basins' effluent 96-hr LC_{50} ranged from 7% to 52%.

There are no limits set in the Control Order for PAH compounds despite their presence at appreciable amounts in Algoma discharges. There are no zinc effluent limits set in the amended control order since measurement through self-monitoring or pilot site investigation programs indicated average concentrations less than the OMOE guideline of 1 mg/L. On occasion, however, daily levels of zinc from the Bar and Strip Lagoon exceeded the 1 mg/L level. The MISA pilot site investigation in 1986 revealed that 12% of samples exceeded 1 mg/L.

ii) St. Marys Paper

The St. Marys Paper Certificate of Approval (C of A) contains limits for only suspended solids. Currently, the suspended solids loading (3 tonnes/d) is well below the C of A requirement (Table VI-28).

iii) Municipal WWTPs

The East End WWTP must achieve, on an annual average basis, a 30% removal of BOD_5 and a 50% removal of suspended solids. In 1985 and 1986 the annual average removal for BOD_5 was 39% and 54%, respectively. The annual average total phosphorus concentration was 4.2 mg/L in 1985 and 3.4 mg/L in 1986. Thus, the BOD_5 and suspended solids requirements were both met in 1985 and 1986; however, the annual average total phosphorus concentration was above the GLWQA objective of 1.0 mg/L.

During the survey, the average BOD_5 removal was 17% and the total suspended solids removal 65% (Table VI-28). Effluent total phosphorus ranged from 2.8 to 3.1 mg/L. The implementation of phosphorus removal facilities, currently scheduled for January 1989, would be necessary to bring the total phosphorus concentration below 1 mg/L. Such facilities would also improve the reduction of BOD_5 and suspended solids. With phosphorus removal facilities in place, this plant would also be required to achieve 50% removal of BOD_5 and 70% removal of suspended solids on an annual basis.

The West End WWTP has only been on line since March 1986. During the first three months of operation the average effluent concentration of total phosphorus exceeded 1.0 mg/L. However, since then the plant has consistently met this requirement. The BOD_5 and suspended solids 20 mg/L limit was achieved on an annual basis and, except for BOD_5 in March 1986, the monthly averages have been consistently below 20 mg/L.

<u>Michigan</u>

The City of Sault Ste. Marie WWTP was not surveyed for the UGLCC Study. Because this plant was upgraded to secondary treatment in 1985 (on line 1986), historical effluent quality data collected prior to this period is no longer applicable. The compliance evaluation based on monthly average concentrations from November 1986 to October 1987 indicated the plant was in full compliance its NPDES permit for BOD_5, suspended solids, pH and phosphorus (Table VI-28).

3. Adequacy of Control Mechanisms

<u>Control Orders</u>

Models developed for the St. Marys River were used to assess the adequacy of effluent requirements stated in the Control Order for Algoma Steel Corp. Ltd. The regulatory mixing zone of 300 m is considered as the allowable zone beyond which no exceedence of water quality objectives is permitted under the expected range of natural conditions. This is based on an assessment of the significance of sites for aquatic, biological and/or human contact. The 300 m zone is recognized as a somewhat arbitrary limit and, after consideration by the RAP process, could be altered.

Table VI-26 indicates the existing discharges from Algoma Steel are exceeding a 300 m regulatory zone. Table VI-29 indicates the loading requirements which will result in levels complying with the OMOE and GLWQA at the boundary of the regulatory zone under average summer river flows. Ammonia and cyanide loadings of 7,000 and 95 kg/d will ensure no toxic effect at the end of the Terminal Basins' outfall. Levels at the boundary of the regulatory zone will be nontoxic during medium and low river flows. The phenol loading requirements (19 kg/d) in the Control Order will result in an exceedence during low river flow conditions but with a frequency of 0.1%.

Loadings of oil and grease and suspended solids stated in the Control Order may not be adequate to protect aquatic life in the river. An assumption that the concentrations of oil and grease and suspended sediment within the water column not exceed the background levels by more than 10% at the edge of the regulatory zone is used to provide adequate protection for aquatic organisms (e.g. Hexagenia). Based on this assumption, the Control Order requirements may have to be decreased to 950 kg/d for oil and grease and 1,900 kg/d for suspended solids. These loadings should be reduced further by about half to meet the requirements of the regulatory zone during low flow conditions. Limiting the oil and grease loadings to about 480 kg/d, should allow the recovery of aquatic organisms that were adversely affected by oil and grease discharges.

4. Ontario Regulatory Initiatives

Under Ontario's new MISA Program (Chapter III) effluent limit regulations will be developed on the basis of Best Available Technology Economically Achievable, for Algoma Steel Corp. Ltd., St. Marys Paper and the two Sault Ste. Marie WWTP's (to be promulgated by 1990/1991).

TABLE VI-29

Adequacy of effluent requirements for Algoma Steel.

Parameters	Control Order Loadings (kg/d)	Loading Requirements (kg/d) to Acheive the Regulatory Zone (300 m)
Ammonia	Reduce ammonia and cyanide to levels below the diagonal line (Fig.VI-32)	7,000
Cyanide		95
Phenol	22.7	19
Oil and grease	1,023	950
Suspended solids	5,100	1,900

H. RECOMMENDATIONS

Surveys of sediment quality, benthic community structure and water quality have revealed an impacted zone along the Ontario shore downstream of the industrial and municipal discharges. This zone was characterized by an impaired benthic community, contaminated sediments (zinc, cyanide, oil and grease, phenols, PAHs) and elevated concentrations of phenols, PAHs, iron, zinc, cyanide, phosphorus, ammonia, and fecal coliform bacteria in surface waters. Notwithstanding reductions in Algoma Steel effluents, impacts still exist in the benthic community in the river. Generally, the studies revealed that biota, sediments and water quality along the Michigan shore of the St. Marys River and in Lake Nicolet were good.

Based on these findings, the following recommendations are made in support of remedial programs already underway and to address the goals identified in Section F.

A. Industrial and Municipal Point Source Remedial Recommendations

1. Ontario and Michigan should incorporate the Great Lakes Water Quality Agreement's goal of the virtual elimination of all persistent toxic substances into their respective regulatory programs.

2. Algoma Steel which was the major contributor of ammonia, phenols, oil and grease, cyanide and suspended solids must continue to reduce loadings of these substances to meet the requirements of the Ontario Ministry of the Environment Control Order, the compliance dates of which should be strongly enforced. This recommendation is subject to recommendations 8 to 10, below.

3. The Sault Ste. Marie, Ontario East End WWTP should be equipped with phosphorus removal in order to bring the total phosphorus concentration in the final effluent down to the required 1 mg/L (this is expected to be on-line in 1989).

4. The treatment capacity of the East End WWTP is frequently exceeded. To reduce the frequency of plant overflows and bypasses this plant must be upgraded to provide secondary treatment and expanded, or a portion of the wastewater must be rerouted to the West End WWTP.

The Sault Ste. Marie, Ontario East End WWTP contributed the highest loadings of benzene-chloroethers and was the second highest contributor of oil and grease, ammonia, chloride, total metals, volatiles, PAHs, chlorinated phenols and phthalates. Elevated levels of PAHs and chlorinated phenols were observed only on the first day of sampling, presumably due to an industrial spill into the sanitary system.

5. The municipality, with the support of the OMOE, take steps to strictly enforce the Sault Ste. Marie Sewer By-Law and thus prevent the discharge of untreated industrial wastes to municipal sewers. The municipality and/or OMOE should also initiate an educational program to discourage home owners from disposing of hazardous or toxic waste in sewers.

6. Discharges of fecal coliform and fecal streptococci from Algoma Steel, WWTPs and combined sewer overflows must be reduced to meet Provincial Water Quality objectives.

7. The A.B. McLean aggregate extraction operations is potentially a significant source of suspended solids to the St. Marys River. The current, permitted extraction must be closely monitored and the requirements must be strictly enforced. Furthermore, the pending permit application must not be issued until a comprehensive environmental review indicates that the increased activity would not result in unacceptable adverse impacts.

In moving toward the virtual elimination of persistent toxic substances, future toxic controls will place increased emphasis on the ambient conditions of the St. Marys River ecosystem.

8. Discharge limits for point sources should be based on mixing zones with all water quality objectives met at the boundary of the mixing zone. This zone is expected to be reduced (ultimately to zero) as advances in treatment technology are implemented.

9. Depending on the parameter, Algoma Steel samples their effluent on a daily, weekly or monthly basis. Most of the controlled parameters are based on 12 month averages. Due to the variability in effluent characteristics, sampling should be more frequent. The frequency and type of sampling should be re-evaluated and audit sampling by OMOE should be increased.

10. Additional parameters, such as PAHs, should be regulated and incorporated into Algoma's monitoring program.

B. Nonpoint Source Remedial Recommendations

Concentrations and estimates of loadings from urban runoff are available only for the Ontario side. Estimates of atmospheric deposition on the Ontario side of the river indicated that significant amounts of PAHs might reach the river through the storm sewers. For rural runoff, loading estimates were available only for the Michigan side.

11. Ontario and Michigan should conduct additional studies for both urban and rural runoff to better identify and quantify loadings of trace inorganic and organic compounds.

Several active and inactive waste sites in Michigan and Ontario were identified as having the potential for contributing contaminants to the St. Marys River. These studies have been limited in scope and do not quantify the magnitude of the contaminant loadings entering the river.

12. Investigate the kinds of contaminants, the pathways of contamination (surface water and groundwater), and the magnitude of the contaminant flux; establish monitoring networks as required; and undertake necessary remedial clean-up activities at the following waste sites:

    i) the Algoma Slag Site;

    ii) Cannelton Industries Tannery disposal site (under CERCLA authority);

    iii) Union Carbide and Superior Sanitation landfills (under Michigan Act 307).

13. Spill containment must be improved at both industrial and municipal facilities to minimize the frequency of shock loadings to the aquatic ecosystem. This will entail spill prevention, development of contingency plans to deal with material reaching the river and following established procedures for the reporting of spills.

C. Surveys, Research and Development

14. Many PAHs have been shown to be bioaccumulative or to have toxic effects on aquatic organisms and some are proven carcinogens. The absence of specific, numerical water quality standards makes it difficult to regulate the discharge of PAHs. An accelerated effort to assess the ecological significance of PAHs and to develop compound specific criteria is required.

15. There are no regulatory guidelines to permit assessment of the biological significance of sediment associated contaminants. Development of such guidelines is required to aid in site-specific evaluations of contaminated sediments.

16. Impacts to benthic macroinvertebrate communities have been related to sediment quality. Further site specific work

must be completed to prioritize sediment "hot spots" based on biological impacts. In addition, physical and chemical characteristics of the sediment should be evaluated. This information will be used to determine appropriate remedial actions for sediments. Suggested studies include acute and chronic sediment bioassays as well as physical/chemical and bedload assessments.

17. The development of water quality based effluent limits for specific PAH compounds requires additional monitoring of point source discharges (water as well as air) and determination of PAH concentrations in resident aquatic indicator species.

18. There is a paucity of data on the near-field atmospheric deposition of metals and organics. This information should be obtained, and evaluated relative to other sources (e.g. effluents, urban runoff, Lake Superior) to the river.

19. Suspended solids are of concern due to their ability to deposit contaminants locally or to transport them long distances, before settling out. An investigation of the combined effects of suspended solids discharges from Algoma Steel, St. Marys Paper, and WWTPs should be completed. This may involve a sediment transport modeling effort that considers the sources, transport and ultimate deposition of sediment and contaminants. This study would also allow prioritization of sources for remedial action.

20. The NPDES Permit for the Sault Ste. Marie, Michigan WWTP includes effluent limits for BOD_5, pH, suspended solids, total phosphorus, fecal coliform, and residual chlorine. No loadings were measured for UGLCCS parameters during the 1986 survey period. Although no adverse impacts on the river ecosystem have been observed, trace contaminant loadings from this facility should be determined to verify the absence of environmentally significant loadings to the river.

21. The OMOE has issued fish consumption advisories for many large game fish due to mercury contamination. Although the main source of mercury is believed to be natural, there are potential sources in the Sault Ste. Marie urban area. Mercury has been detected, for example, in all point source effluents and in stormwater in Sault Ste. Marie, Ontario. Therefore, it is recommended that a study to determine the relative contributions of background and urban source(s) of mercury be completed.

22. Fecal coliform bacteria densities were detected in river water downstream of the Edison Sault Power Canal in Michigan. Further sampling must be conducted to determine

whether Michigan's fecal coliform standard is being exceeded and, if so, to identify the source(s) and appropriate remedial action.

23. For chemicals where ambient data and standards are available, the agencies must develop an ecosystem model. The model should provide insight into the fate of chemicals entering and leaving the river by various pathways as well as a systematic process for predicting the relative effectiveness of proposed corrective actions.

24. Although the current water quality objective for oil and grease is narrative (i.e. no visible sheen), a numerical objective should be developed that is based on no adverse impacts on sediment quality and associated benthos.

I. LONG TERM MONITORING

1. UGLCCS vs. Other Monitoring Programs

A presentation of the purposes for monitoring and surveillance activities is included under Annex 11 of the GLWQA and a discussion of considerations for the design of a long term monitoring program can be found in Chapter 7 of the Report of the Niagara River Toxics Committee (59). Because the focus of the UGLCC Study was toward remedial actions to alleviate impaired uses of the Connecting Channels System, long term monitoring recommendations will likewise focus on the evaluation of trends in environmental quality in order to assess the effectiveness of remedial actions. In general, post-UGLCCS monitoring should be sufficient to 1) detect trends in conditions noted by the UGLCCS, and 2) detect changes in ambient conditions which have resulted from remedial actions. Monitoring programs should be designed to specifically detect the changes intended by the remedial actions so as to ensure relevance in both temporal and spatial scales.

Two major programs sponsored by the IJC also contain plans for long term monitoring: the Great Lakes International Surveillance Plan (GLISP) and the Remedial Action Plans (RAPs) for Areas of Concern (AoC's) identified by the IJC. The GLISP for the Upper Great Lakes Connecting Channels is presently incomplete, pending results of the UGLCC Study, but it is expected to provide monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the GLWQA that include general surveillance and research needs as well as monitoring for results of remedial actions.

The St. Marys River is one of the AoCs, and a RAP is being developed jointly by Michigan and Ontario. The RAP will identify uses impaired, sources of contaminants, desired use goals, target clean-up levels, specific remedial options, schedules for implementation, resource commitments by Michigan and Ontario as well as by the federal governments, municipalities and industries and monitoring requirements to assess the effectiveness of the remedial options implemented. Results and recommendations coming from the UGLCC Study will be incorporated extensively into the RAP, which will then be the document that influences federal, state and provincial programs for the St. Marys River. The recommendations for long term monitoring that are presented below are intended for consideration and incorporation into either or both the GLISP and RAP for the St. Marys River.

2. System Monitoring for Contaminants

Water

Knowledge of the concentrations of the principal contaminants in the water of the St. Marys River should be used to indicate general exposure levels for the biota, to identify changes and trends over time in the concentration levels, and to be used for general assessment of contaminant impacts. The parameters to be monitored include phenols, iron, cyanide, ammonia, total PAHs, oil and grease, benzo(a)pyrene, and ether solubles. Monitoring stations should provide information on contaminant concentrations throughout the river. For continuity, these should include the sampling transects identified in this study (i.e., SMU 1.0 and 0.5; SMD 0.2, 1.0, 1.2, 2.6, 4.2E, and 5.0E). Sampling frequency should be influenced by the variability in contaminant sources. Spring high flow conditions and late summer low flow conditions would be expected to bracket the normal seasonal variability in flow that could influence measured contaminant concentrations.

A mass balance approach to contaminant monitoring will help to identify any changes in the contaminant mass over time, and it will provide the basis for targeting future remedial actions by providing a comparison of the magnitude of the sources. A mass balance analysis should be conducted approximately once every five years, assuming that some effective remedial action has been implemented against one or more sources such that the total loadings of contaminants, or the relative contribution of the sources to the loading, has changed. The sources to be measured should include:

1) Head and mouth transects for upstream and downstream boundary movements. The number and locations of stations should relate to measured or predicted plume distributions. Suggested locations include Point Aux Pins, the head of Sugar Island, and the downstream end of Lake George and Lake Nicolet. Both dissolved and particulate fractions should be analyzed. The quantity of suspended sediment flux should also be measured.

2) Municipal and industrial point sources. During the survey, the sampling must be frequent enough to accurately reflect the likely loading fluctuations from the major point sources. The sources include the major outfalls of Algoma Steel, St. Marys Paper, and the East End WWTP, the West End WWTP and Sault Ste. Marie, Michigan WWTP.

3) Tributaries. Preliminary assessment has shown that contributions from tributaries to the St. Marys River are secondary to the industrial and municipal point sources. These findings should be confirmed periodically.

4) CSOs and Runoff. To provide an estimate of contaminant mass loadings expected during storm events, occasional studies on selected urban drainage areas should be conducted. Estimates should be made for all urban and agricultural runoff on both sides of the river.

5) Groundwater inflow. Groundwater monitoring systems designed to detect potential loadings to the St. Marys River need to be installed at the Algoma Slag Site and at Cannelton Industries Tannery disposal site following remediation. The existing monitoring system at the Cherokee Landfill should be utilized to detect potential loadings to the river.

6) Sediment transport. Preliminary studies indicate that bedload sediments moving into and out of the St. Marys River carry contaminant masses similar to, or exceeding the other sources. The mass flux should be quantified.

7) Atmospheric deposition. Direct atmospheric deposition of contaminants to the St. Marys River is expected to be minor. Deposition to the drainage basin and subsequent runoff into the river or its tributaries, however, could be an important source for some contaminants. Estimates of contaminant mass in both wet and dry deposition to the drainage basin should be made when unidentified nonpoint sources are found to be a major contributor of any of the contaminants of interest.

Sediments

Monitoring of sediments for concentrations of contaminants should be conducted periodically throughout the St. Marys River in order to assess both the trends in surficial contaminant concentrations and the movement of sediment-associated contaminants within the river. The grid used by the U.S.FWS during the 1985 survey would be appropriate for consistency in sampling sites and sediment composition. An analysis of sediment chemistry including both bulk chemistry, organic and inorganic contaminants, and particle size distribution should be conducted every 5 years, in conjunction with a biota survey (see "habitat monitoring" below). In the St. Marys River, particular attention should be given to sediment concentrations of oil and grease, phenols, cyanide, and PAHs.

Because the grid stations are distributed throughout the river reach and are associated with appropriate habitat for a sensitive benthic invertebrate (Hexagenia), the periodic survey will allow assessment of 1) contaminant distribution throughout the river sediments, 2) relative movement of the contaminants within the river sediments between surveys, and 3) correlation of contaminant concentrations with benthic biotic communities.

The sediment at any stations established at the mouths of tributaries to the St. Marys River should be monitored for organic and inorganic contaminants on an annual or biannual basis when significant remedial actions are implemented within the watershed for the tributary. The remedial actions should be expected to measurably reduce loadings of one or more particular contaminants via the tributary in order to trigger the more frequent sediment monitoring programs.

Biota

Long term monitoring of concentrations of contaminants in biota will provide a time series useful to track the bioavailability of contaminants to selected representative organisms. Three long-term monitoring programs are already in place and should be continued:

i) Annual or bi-annual monitoring of sport fish.

This program should focus especially on PAHs, mercury, and PCBs. The monitoring should be continued regardless of the differences that may be observed between acceptable concentrations or action levels that may be established by governmental agencies and the measured contaminant concentrations in the fish flesh. As a link between human health concerns and integrated results of remedial programs to reduce contaminants in the UGLCC System, this program is critically important.

ii) Spottail shiner monitoring program.

This program is designed to identify source areas for bioavailable contaminants. In locations where spottail shiners contain elevated levels of contaminants, additional studies should be conducted to identify the sources of the contaminants. Some upstream studies in tributaries may be required. Spottails should also be employed to confirm that remedial actions have been effective in removing or reducing the loading of one or more contaminants.

iii) Caged clams contaminants monitoring.

Caged clams should continue to be used at regular time intervals, perhaps in conjunction with spottail shiners, to monitor integrated results of remedial actions to reduce contaminant loadings to the water. Clams may be located at tributary mouths and downstream of suspected source areas. Repeated assays from the same locations should confirm results of remedial actions.

iv) Benthic survey

The macrozoobenthic community should be evaluated at least every 3 years. As a minimum, the abundance and distribution of the mayfly Hexagenia should be determined to serve as an indicator species of environmental quality. The grid used by the U.S.FWS during the 1985 survey (Figure VI-20) would be appropriate for consistency in sampling sites each survey. An analysis of sediment chemistry, including bulk chemistry, organic, inorganic and extractable (available) contaminants, and particle-size distribution, should be conducted for samples taken concurrently with the macrozoobenthic survey. These data will provide information on the quality of the benthic habitat.

v) Toxicity testing

Sediment toxicity tests, using whole sediment and sediment pore water or elutriate should be conducted at selected sites in conjunction with the benthic survey. Results will assist to differentiate between toxicity and substrate or dissolved oxygen effects.

3. Sources Monitoring

Remedial actions intended to reduce concentrations and/or loadings of contaminants from specific point sources generally require monitoring for compliance with the imposed criteria or standards for permitted contaminants. The monitoring may be conducted by the facility or by the regulating agency, whichever is applicable, but attention must be given to the sampling schedule and analytical methodology such that mass loadings of the contaminants can be estimated, as well as concentrations in the sampled medium. Monitoring of the "near-field" environment, i.e., close downstream in the effluent mixing zone, should be conducted regularly to document reductions in contaminant levels in the appropriate media and to document the recovery of impaired ecosystem processes and biotic communities. Such monitoring may be required for a "long time", but over a restricted aerial extent, depending on the severity of the impact and the degree of reduction of contaminant loading that is achieved.

For the St. Marys River, four actions were recommended that would affect specific sources of contaminants:

a) Reduction of toxic substances from Algoma Steel effluents, especially at the Terminal Basins. Reductions in loadings of phenol, cyanide, ammonia, oil and grease, and suspended solids are expected as a result of new effluent limitations imposed as part of the MISA program. Monitoring of sediments and biota for contaminant concentrations and effects downstream of the effluent should be conducted regularly to document any improvement in environmental conditions.

b) Enforcement of the regulatory mixing zone for the Sault Ste. Marie, Ontario East End WWTP. Ontario must design a monitoring plan adequate to determine that all water quality objectives are met at the boundary of the regulatory zone, and to determine if adverse environmental effects continue in the sediments and biota despite compliance with water quality objectives.

c) Enforcement of the Sault Ste. Marie, Ontario Sewer By-Law to prevent the discharge of untreated industrial wastes or contaminants disposed by homeowners into municipal sewers. Ontario will provide additional monitoring, inspection and enforcement tools for implementing controls of toxic discharges to sewer systems. The monitoring component must include assessment of continuing environmental effects in sediments and biota downstream of the sewer outfall, as well as monitoring for concentrations of selected contaminants in the sewer influent.

d) Equip the Sault St. Marie, Ontario, East End WWTP with phosphorus removal facilities. Frequent in-plant monitoring will be required to document that the target discharge limit of 1 mg/L is being met.

Other recommendations for specific contaminant sources involve an assessment of the present conditions or a study to quantify concentrations or loadings: review of PAHs for risk and hazard information; assess the need for further reduction of suspended solids from St. Marys Paper; quantify trace contaminants from the Sault St. Marie, Michigan WWTP, estimate loadings of trace organic and inorganic compounds from urban and rural runoff, and quantify potential releases of contaminants from waste disposal sites. Each of these items requires a specific program of data collection and analysis. Additional needs for longer term monitoring may be identified as a result of these studies.

4. Habitat monitoring

Habitat monitoring should be conducted to detect and describe changes in the ecological characteristics of the St. Marys River through periodic analysis of key ecosystem elements. In particular, quantification of the extent of wetlands along the St. Marys River should be conducted every three years. Aerial photography or other remote sensing means would be appropriate to discern both emergent and submergent macrophyte beds that are important as nursery areas for larval fish and other wildlife. Verification of aerial data should be conducted by inspection of selected transects for plant species identification and abundances. Changes in wetland areas should be correlated with fluctuating water levels and other natural documentable influences so that long term alterations in wetlands can be tracked and causes identified.

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